Vol. 12 No. 3 JULY, 1958

BRITISH JOURNAL OF PREVENTIVE & SOCIAL MEDICINE

SEP 27 1958

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CONTENTS

PAGE

Congenital Malformations of the Central Nervous System in Scotland. J. H. Edwards .. 115

Post-Neonatal Infant Mortality in Birmingham between 1947 and 1956. George Knox and Jean Mackintosh .. 131

Tuberculosis in Immigrants in Birmingham, 1956–1957. V. H. Springett, J. C. S. Adams, T. B. D'Costa, and M. Hemming .. 135

A Note on the Interpretation of $n \times 2$ Tables. J. H. Edwards .. 141

Coronary and Other Heart Disease in a Group of Irish Males aged 65–85. Roy M. Acheson and E. Donald Acheson .. 147

A New Method of Standardizing Death Rates. D. Kerridge .. 154

Hospital Size and Staff Sickness Rates. A. Barr .. 156

LONDON
BRITISH MEDICAL ASSOCIATION
TAVISTOCK SQUARE, W.C.1

YEARLY SUBSCRIPTION (4 NUMBERS) £3 U.S.A. $10.00 SINGLE NUMBER 17s. 6d.

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Brit. J. prev. soc. Med. (1958), **12**, 115–130

CONGENITAL MALFORMATIONS OF THE CENTRAL NERVOUS SYSTEM IN SCOTLAND

BY

J. H. EDWARDS

From the Department of Social Medicine, University of Birmingham

The reports of the Registrar General for Scotland provide information not available elsewhere on the causes of stillbirth as well as detailed reports on neonatal deaths. Data on the common causes of stillbirth have been available since 1939, by month of birth, maternal age, maternal parity, and legitimacy, and since 1950 by social class of father and place of birth also.

The present communication considers data relating to stillbirths due to anencephalus, spina bifida, and hydrocephalus, and to infant deaths due to spina bifida and hydrocephalus.

Social Class and Legitimacy

The marked association of foetal defect with class was first advanced on adequate data in the report of the Registrar General for Scotland in 1950. An analysis of the incidence of stillbirths due to malformations of the central nervous system according to class and legitimacy is given in Table I and Fig. 1. The steep trend is striking. The association explains about a quarter of the social variation in stillbirth rate. That is to say, at least a quarter of the social variation in this rate is irrevocably determined by the time a woman attends an antenatal clinic.

TABLE I

INCIDENCE (PER 1,000 TOTAL BIRTHS) OF MALFORMATIONS OF THE CENTRAL NERVOUS SYSTEM IN LEGITIMATE BIRTHS ACCORDING TO SOCIAL CLASS OF FATHER AND IN ILLEGITIMATE BIRTHS. SCOTLAND, 1950–56 (Stillbirths only).

Type of Malformation	Social Class (Legitimate Births)					Illegitimate Births
	I	II	III	IV	V	
Anencephalus	0·89	1·74	2·74	2·97	3·60	2·75 (2·89)
Spina Bifida ..	0·17	0·23	0·29	0·33	0·31	0·3 (0·3)
Hydrocephalus	1·01	0·99	1·35	1·46	1·55	2·11 (1·40)
All	2·1	3·0	4·4	4·8	5·5	5·1 (4·6)

The figures in brackets are the incidences expected from the social class distribution of these illegitimate births for which data are available.

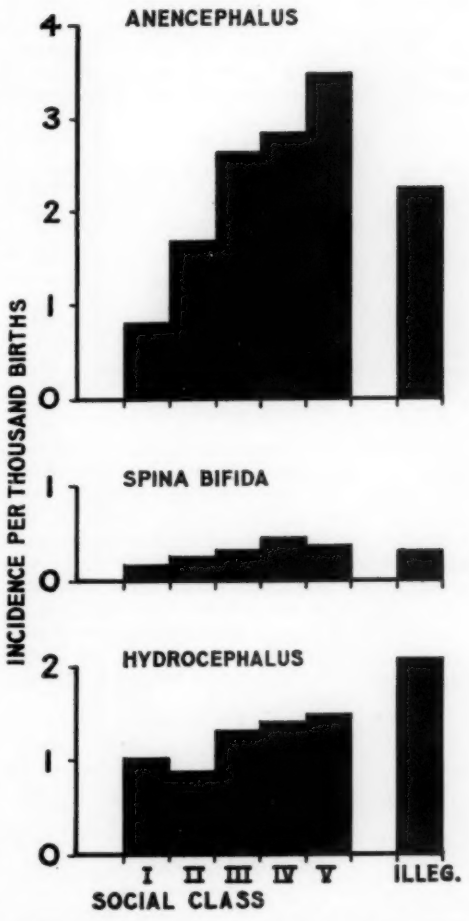

FIG. 1.—Incidence of stillbirths with malformations of the central nervous system in Scotland, 1950–56, by social class and legitimacy.

The incidence of anencephalus in illegitimate births is considerably lower than considerations of class and parity might suggest. In Birmingham, Record and McKeown (1949) found eight illegitimate anencephalics against an expectation, without standardizing for parity, of 15·3. In spina bifida the few cases in illegitimate stillbirths are not suggestive of any influence of illegitimacy, and agree, in this, with the Birmingham data. In hydrocephalus there is a considerably higher incidence in illegitimate births than in legitimate births in the years 1950–1956. A comparison of the numbers of illegitimate stillbirths with those expected, if the incidence was the same as in legitimate births in Scotland from 1939–1949 (Table II), confirms that anencephalus is less common in illegitimate births: however the apparent increase in risk in hydrocephalus cannot be confirmed in these years.

TABLE II

THE NUMBER OF ILLEGITIMATE STILLBIRTHS WITH MALFORMATIONS OF THE CENTRAL NERVOUS SYSTEM COMPARED WITH THOSE EXPECTED WITHOUT STANDARDIZATION FOR PRIMIPARITY OR CLASS. SCOTLAND 1939–49.

Type of Malformation	Observed (*a*)	Expected (*b*)	Ratio *a* : *b*
Anencephalus ..	165	176	0·94
Spina Bifida	31	30·3	1·0
Hydrocephalus ..	101	104	0·97

PARITY

The form in which the Scottish data are presented limits any independent analysis by maternal age and parity. We may, however, obtain a fairly precise estimate of the relative liability in first births compared with second births, since the mean interval between these births is small, so that maternal age, like class, has in these conditions only a slight and conservative bias. The ratio of numbers of first born to second born in the affected (Table III), divided by that ratio in the control population, gives this relative liability (Table IV).

TABLE III

RATIO OF NUMBERS OF FIRST TO SECOND BIRTHS

Type of Malformation	Scotland (Stillbirths) 1950–1956	Birmingham*	Rhode Island†
Anencephalus	1·85	2·03	2·18
Spina Bifida	1·94	2·06	2·16
Hydrocephalus	1·82	1·38	2·43
Control	1·34	1·14	1·41

*Record and McKeown (1949).
†Ingalls, Pugh, and MacMahon (1954).

TABLE IV

RATIO OF NUMBERS OF FIRST TO SECOND BIRTHS IN AFFECTED DIVIDED BY RATIO IN CONTROL POPULATION

Type of Malformation	Scotland	Birmingham	Rhode Island
Anencephalus	1·38	1·8	1·5
Spina Bifida	1·45	1·8	1·5
Hydrocephalus	1·36	1·3	1·7

This ratio, being based on stillbirths, will also reflect any variation with parity in the proportion of malformed foetuses surviving birth. In anencephalus this proportion is too slight to lead to more than a slight exaggeration of this ratio, but in the case of spina bifida and hydrocephalus the increased hazards of first births and the larger proportion surviving might be expected to considerably exaggerate this ratio. Data collected in Birmingham and Rhode Island, which are based on both stillbirths and infant deaths, are therefore shown alongside the Scottish figures. The consistency of the three series suggests that no gross bias is introduced by restricting attention to stillbirths. In Scotland there is clear evidence in each condition of a relative increase in risk to the foetuses of primiparae of almost a half.

MATERNAL AGE

In anencephalus and hydrocephalus, but not in spina bifida, there is a U-shaped distribution of incidence with maternal age, the incidence falling until about 25 years, and then rising fairly steeply. The proportion of first births is, of course, much higher in young women, and, if we make the assumption that the relative increase in liability due to primogeniture is constant by age and class, we may eliminate this bias by weighting the controls to contain the appropriate excess of primiparae and the appropriate proportion of each social class. An examination of the Birmingham series showed that age did not appear to influence the primogeniture effect in anencephaly, spina bifida, or hydrocephalus.

The relative liabilities at each maternal age are given in Table V and Fig. 2 (opposite). Because of the small effects of standardizing for class, and the almost equal primogeniture effect in each condition, the standardization has not appreciably influenced the comparative effects of maternal age on the three conditions. Each shows a steeply rising trend with maternal age, the relative liability at age 40–44, compared with that at 20–24, being doubled in

TABLE V

RELATIVE INCIDENCE OF STILLBIRTHS BY CENTRAL NERVOUS MALFORMATION ACCORDING TO MATERNAL AGE, STANDARDIZED TO REMOVE VARIATION DUE TO SOCIAL CLASS AND PRIMIPARITY

Type of Malformation	Maternal Age (yrs)						
	Under 20	20–	25–	30–	35–	40–	45 and Over
Anencephalus	1·40	1·00	0·97	1·12	1·49	1·81	*0·98*
Spina Bifida	*0·5*	1·00	1·33	1·94	2·36	3·40	*13·4*
Hydrocephalus	1·47	1·00	1·22	1·67	2·02	2·27	*4·37*

Rates based on less than ten cases are shown in italics.

anencephalus and hydrocephalus and trebled in spina bifida.

However, it is not possible to distinguish between the contribution due primarily to maternal age and that consequent on parity; it is possible that the maternal age effect is largely due to the incidence increasing with parity, independently of social class and to the close association of maternal age and parity.

Since the data are restricted to stillbirths, and only about one-fifth of cases of spina bifida, and two-thirds of hydrocephalics, are stillborn, the increasing incidence with maternal age may to some extent reflect an increasing proportion of cases being stillborn at higher maternal ages. The trends are smooth, and it does not appear likely from the Figure that the relatively high rates of anencephalus and hydrocephalus in women under 20 are sampling effects. It may, however, be due to the primogeniture effect being more marked in very young women. Attempted abortion is unlikely to predispose to anencephalus very frequently as it is no commoner among illegitimate births. There is also direct evidence confirming this (Whitehouse and McKeown, 1956).

REGIONAL VARIATION

The incidence of each malformation shows distinct geographical variation (Table VI and Fig. 3, overleaf).

In each the range in incidence varies by a factor of at least two. In general, the incidence in the Lowlands exceeds that in the Highlands, but there is no particular association with the great industrial areas which show for each condition an incidence similar to that of the surrounding country. Direct inspection shows a greater concordance between spina bifida and anencephalus than between either

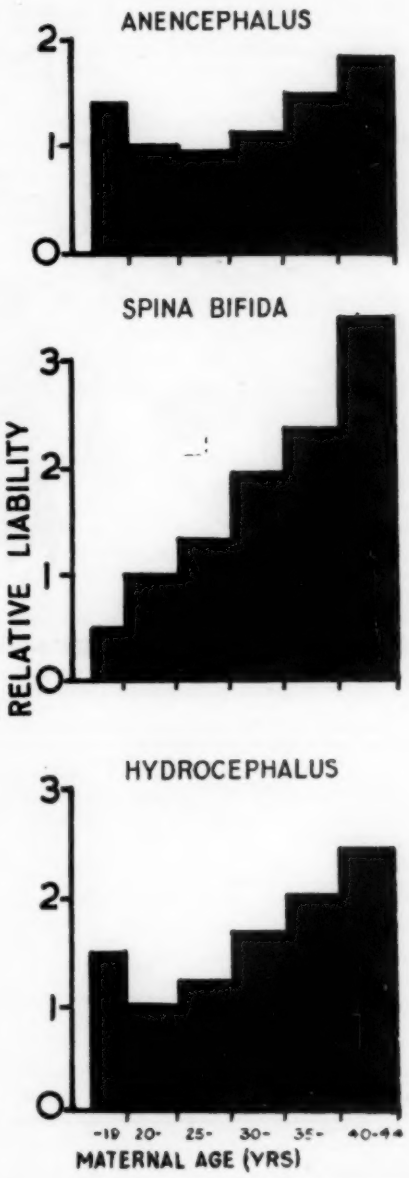

FIG. 2.—Relative liability to stillbirth from malformations of the central nervous system, by maternal age. Corrected for primiparity and class, but not for parity.

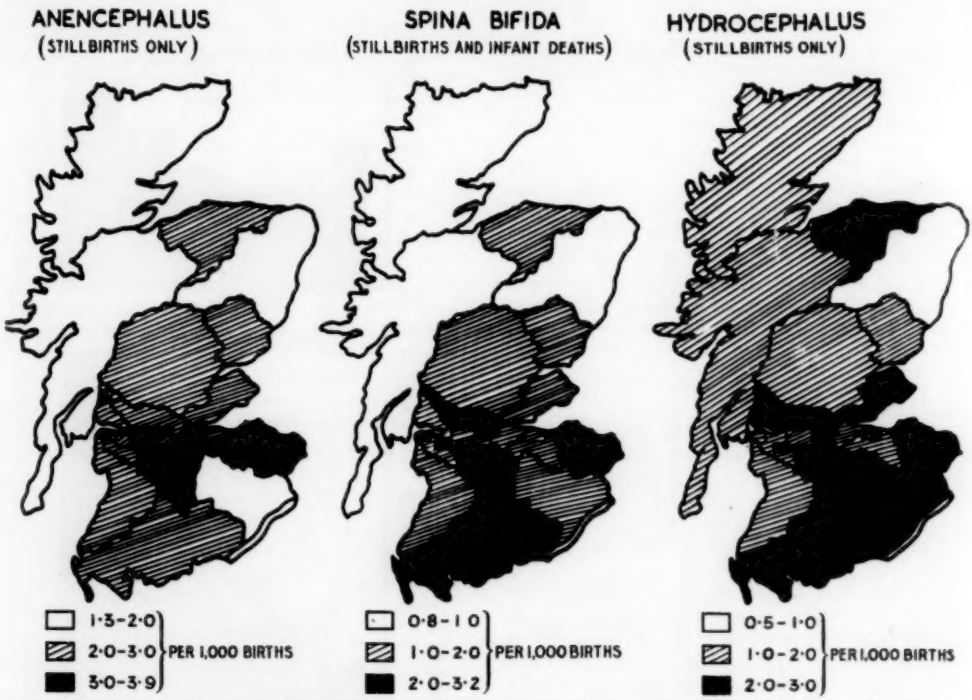

FIG. 3.—Incidence of malformations of the central nervous system in Scotland, 1950–56, per thousand births (see key to each diagram).

TABLE VI

INCIDENCE OF MALFORMATIONS OF THE CENTRAL NERVOUS SYSTEM BY REGION. SCOTLAND 1950–56

Region	Anencephalus (Stillbirths)	Spina Bifida (Stillbirths and Infant Deaths)	Hydrocephalus (Stillbirths)
Aberdeen Burgh Remainder Aberdeen Co. Kincardine County	1·62	0·90	0·72
Arbroath Burgh Dundee Burgh Remainder Angus Co.	2·81	1·76	1·26
Argyll County Inverness Burgh Remainder Inverness	1·44	*0·92*	*1·10*
Ayr Burgh Kilmarnock Remainder Ayr Co.	2·90	1·92	1·32
Banff County Moray County Nairn County	2·55	1·77	1·49
Berwick Co. East Lothian Co.	3·46	*2·12*	*2·57*
Caithness County Ross and Cromarty Co. Sutherland Co.	*1·53*	*0·93*	*1·44*
Clackmannan County Kinross County Perth Burgh Remainder Perth Co.	2·63	1·92	1·42
Dumfries Burgh Remainder Dumfries Co. Kircudbright County Wigtown County	2·94	3·10	1·55
Clydebank Burgh Dumbarton Burgh Remainder Dumbarton County	2·44	1·85	1·59
Dunfermline Burgh Kircaldy Burgh Remainder Fife Co.	2·73	1·75	1·84
Glasgow Burgh	3·01	1·81	1·37
Airdrie Burgh **Coatbridge Burgh**	3·10	2·17	2·01
Hamilton Burgh **Motherwell and Wishaw Burgh** **Rutherglen Burgh**	2·76	1·07	1·51
Remainder Lanark Co.	3·09	2·45	1·59
Edinburgh	2·69	1·41	1·06
Remainder Midlothian	3·81	*1·59*	*1·39*
Roxburgh County Peebles County Selkirk County	*1·71*	*1·48*	*1·82*
Paisley Burgh	2·21	2·13	*1·56*
Port of Glasgow Burgh **Greenock Burgh**	3·85	2·52	*1·13*
Remainder Renfrew Co.	2·44	1·56	*1·00*
Stirling Burgh Falkirk Burgh Remainder Stirling Co.	2·53	2·16	1·47
West Lothian County	3·27	*1·92*	*1·36*

Areas in heavy type represented by rectangles on maps (Fig. 3).
Figures in italics based on less than 25 cases.

of these and hydrocephalus, and this is confirmed by rank correlations for the 23 areas (Table VII).

TABLE VII

REGIONAL RANK CORRELATIONS BETWEEN INCIDENCES OF ANENCEPHALUS, SPINA BIFIDA, AND HYDROCEPHALUS

Malformation	Anencephalus	Spina Bifida	Hydrocephalus
Spina Bifida ..	+0·57		
Hydrocephalus..	+0·18	+0·40	
Post Neonatal Death Rate ..	+0·35	+0·37	+0·31

These positive correlations are to some extent due to the association between the incidence of each condition and social class; this probably explains the correlation with post-neonatal death rates.

It is convenient to explore urban/rural variations of incidence in the larger towns and smaller cities, as the two main cities, having large ports, are likely to be partly populated by seaborne immigration and not genetically comparable to their surrounding country. Analysis shows a considerable and consistent increase in risk of spina bifida attributable to urbanity, but no association between urbanity and anencephalus or hydrocephalus (Table VIII). The method of analysis is described in Appendix A.

LONG-TERM SECULAR TRENDS

The proportion of all births resulting in each of the three common malformations of the central nervous system varies considerably from year to year (Fig. 4, overleaf), and there appears to be little concordance between any pair (Table IX).

TABLE IX

RANK CORRELATIONS IN THE INCIDENCE OF MALFORMATIONS OF THE CENTRAL NERVOUS SYSTEM, 1939–56.

Anencephalus and Spina Bifida	+0·09
Anencephalus and Hydrocephalus	+0·24
Spina Bifida and Hydrocephalus	−0·18

It is remarkable that the war years show no special feature, and that, although improved social conditions have led to a great reduction in most other causes of stillbirth and neonatal death, these malformations which are much commoner in association with low social class, have shown no sustained decrease. Although there is no suggestion of any trend, there are considerable annual variations which are too great to be explained by varying parity distributions. In the case of spina bifida and hydrocephalus the small numbers of stillbirths do not allow any more detailed breakdown. In anencephalus, however, we may attempt to define some features of this extra-ordinary variation in terms of various subgroups.

TABLE VIII

COMPARISON OF URBAN AND RURAL INCIDENCE OF MALFORMATIONS OF THE CENTRAL NERVOUS SYSTEM

Regions		Anencephaly			Spina Bifida			Hydrocephalus		
Urban	Rural	Urban/Rural Ratio	Natural log of Ratio	*t*	Urban/Rural Ratio	Natural log of Ratio	*t*	Urban/Rural Ratio	Natural log of Ratio	*t*
Aberdeen Burgh	Remainder of Aberdeen County	1·14	+0·131	17·3	1·50	+0·405	8·3	0·83	−0·185	8·0
Dundee Burgh, Arbroath Burgh	Remainder of Angus County	1·18	+0·167	17·6	1·93	+0·657	8·4	0·72	0·324	10·0
Ayr Burgh, Kilmarnock Burgh	Remainder of Ayr County	0·84	−0·174	21·6	1·68	+0·519	19·0	0·84	−0·171	10·0
Dumfries Burgh	Remainder of Dumfries County	*1·11*	+0·110	6·6	1·98	+0·683	5·7	*1·70*	+0·531	4·4
Dunfermline Burgh, Kircaldy Burgh	Remainder of Fife County	1·07	+0·068	23·3	1·12	+0·113	15·4	1·25	+0·223	6·9
Inverness Burgh	Inverness County	*0·69*	−0·371	11·5	*2·59*	+0·952	2·9	*2·00*	+0·693	4·7
Perth Burgh	Remainder of Perth County	1·11	+0·110	7·5	*0·82*	−0·198	6·2	*0·55*	−0·605	3·8
Falkirk Burgh, Stirling Burgh	Remainder of Stirling County	0·87	−0·139	12·9	*0·83*	−0·186	1·1	0·78	−0·247	7·4
Weighted Mean		1·0	−0·013 ± 0·092		1·5	+0·390 ± 0·121		1·0	−0·018 ± 0·124	

Numbers in italics are based on ratios involving less than ten observations.

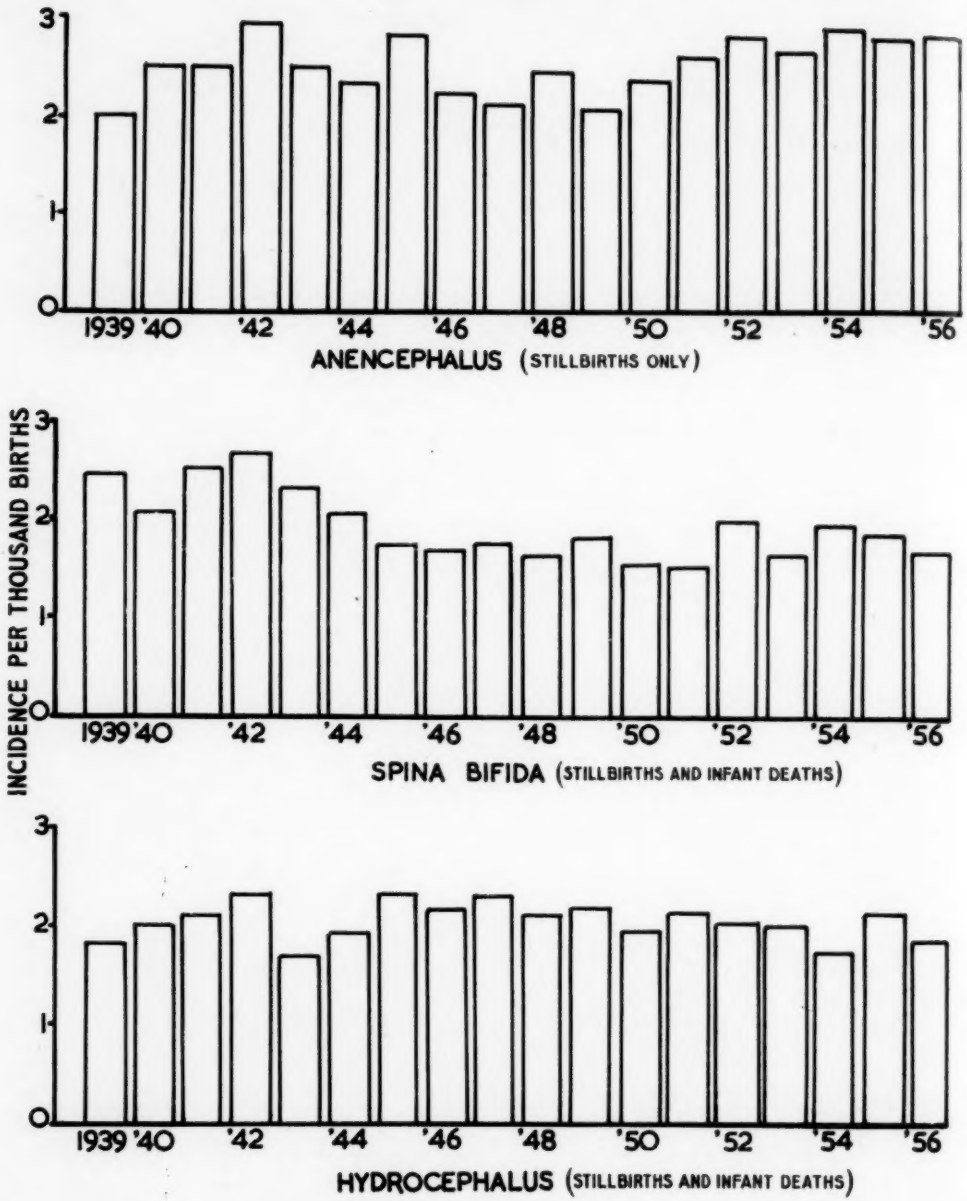

FIG. 4.—Incidence of malformations of the central nervous system in Scotland, 1939 to 1956, per year, per thousand births.

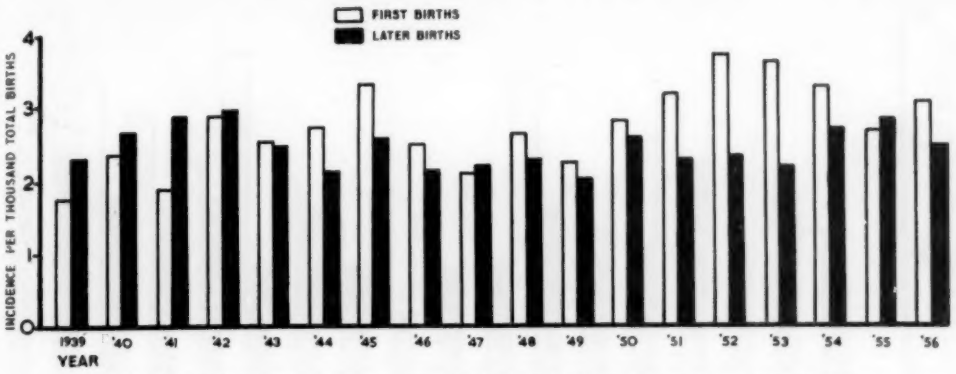

FIG. 5.—Incidence of anencephalus in first and later births in Scotland, 1936 to 1956, per year, per thousand births.

If we consider the incidence in first and in all other birth ranks separately (Fig. 5), it is clear that the greater part of the variation is due to a varying incidence in first births, and that the incidence in these births appears to vary independently of that in later births, which it does not always exceed (Fig. 6).

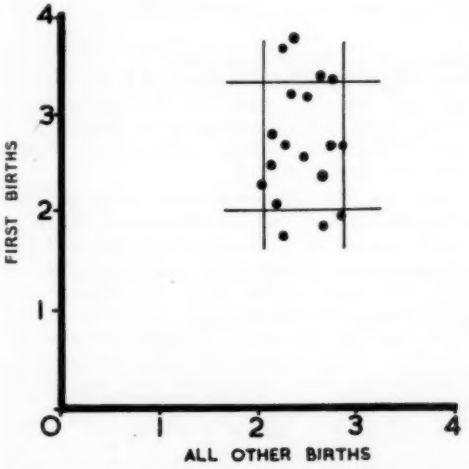

FIG. 6.—Incidence of anencephalus in first and later births. Parallel lines represent approximate 95 per cent. range expected if the variation were entirely due to chance.

The recent rise and fall in incidence between 1950 and 1956 is almost entirely confined to first births. Unfortunately we cannot identify the first births by maternal age, place, season, or social class, and in attempting to invent the body of any contingency table by inferences based in the margins it is all too easy, as in the tobacco-air pollution controversy, to make inferences which can be shown to be formally irrelevant to the data. The most economical explanation however, confirms the suggestion of MacMahon, Pugh, and Ingalls (1953) that the extra risk to first births may be considerably influenced by the environment of the mother. In addition it may be worth pointing out that in Social Class V the numbers of cases of anencephalus in 1950, 1951, and 1952 was 24, 39, and 49 respectively in an almost constant number of births.

In view of the known seasonal variation in anencephalus (McKeown and Record, 1951), we may also break down the secular pattern into winter and summer births, taking the last quarter of one year and the first quarter of the next as winter, and the middle quarters of the year as summer. Fig. 7 (overleaf) shows the winter and summer incidences separately.

Although of doubtful meaning except as comparative indices, it may be of interest to present the rank correlation coefficients between various incidences and ratios (Table X, overleaf).

Each coefficient has a standard error of sampling of about 0·25.

The variation in incidence in winter births is considerably greater than in summer births, the fluctuations of which hardly exceed those to be expected from chance. This suggests that the variations in incidence are largely due to some very variable influence acting on some pregnancies in the summer months. Attempts to associate these variations with notifiable diseases have not been successful. The absence of any association of

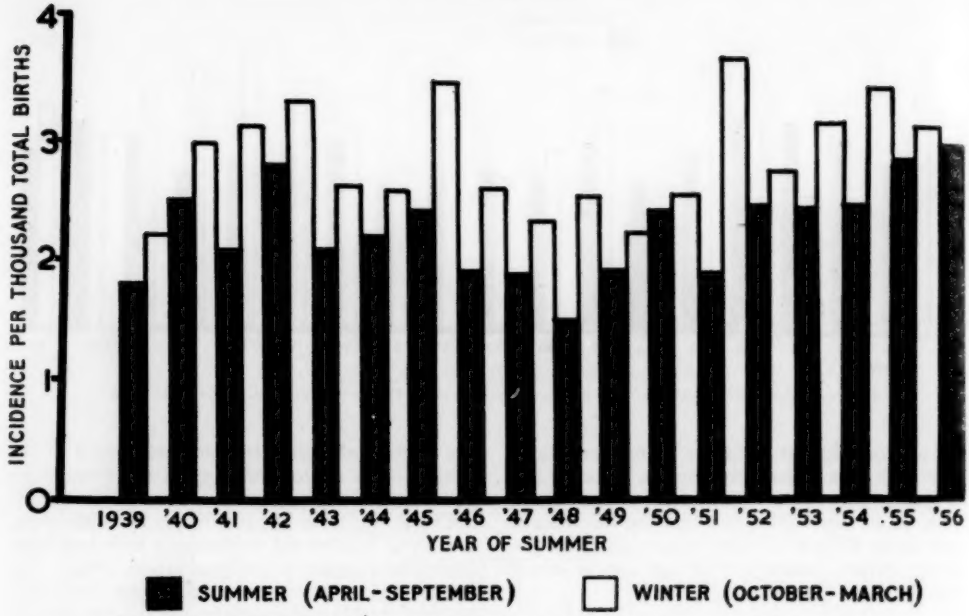

FIG. 7.—Incidence of anencephalus in winter and summer in Scotland, 1939 to 1956, per year, per thousand births.

TABLE X

RANK CORRELATIONS IN ANENCEPHALUS, 1939–56

Male proportion and Winter*/Summer ratio	−0·45
First born/Later born ratio and Winter*/Summer ratio	−0·04
Male proportion and First born/Later born ratio ..	−0·24
Incidence in first births and Incidence in later births..	+0·04
Summer incidence and Incidence in preceding winter†	+0·18
Summer incidence and Incidence in following winter†	+0·53
Mean summer temperature and Incidence in following winter†	−0·05

*Winter defined as first and last quarters of same year.
†Winter defined as last and first quarters of successive years.

winter incidence with the mean temperature of the preceding summer is not suggestive of any direct climatic effect.

The fact that variations in incidence appear to be dominated both by first births and by winter births suggests that the influence of season is more marked on first births, as MacMahon and others (1953) have suggested with reference both to the data from Birmingham (McKeown and Record, 1951) and to their data from Rhode Island. However, if a harmonic curve is fitted to the data on first and other births in Birmingham, the difference in seasonal variation is found to be very slight (±28 per cent. for first born and ±26 per cent. for later born). The seasonal swing in Birmingham was somewhat more marked than that in Scotland (±15 per cent.). The method is described in Appendix B.

The sex ratio in anencephalus shows variation from year to year, and MacMahon and McKeown (1952) showed, at a formally significant level, that the proportion of males was considerably lower in first births than in later births. The negative rank correlations found between the proportion of first births and the proportion of males confirms this (Table X), but the rather larger negative correlation between the male proportion and the winter/summer ratio suggests, once again, that part of this variability is due to a varying risk to first pregnancies conceived in spring and summer. The rank correlation coefficient between the first born/later born ratio and the winter/summer ratio is close to zero: however, it has a large standard error (0·25), and it involves the unsatisfactory definition of winter as the first and last quarters of the same year.

Finally, we may present a comparison of the infant death rates for Scotland and for England

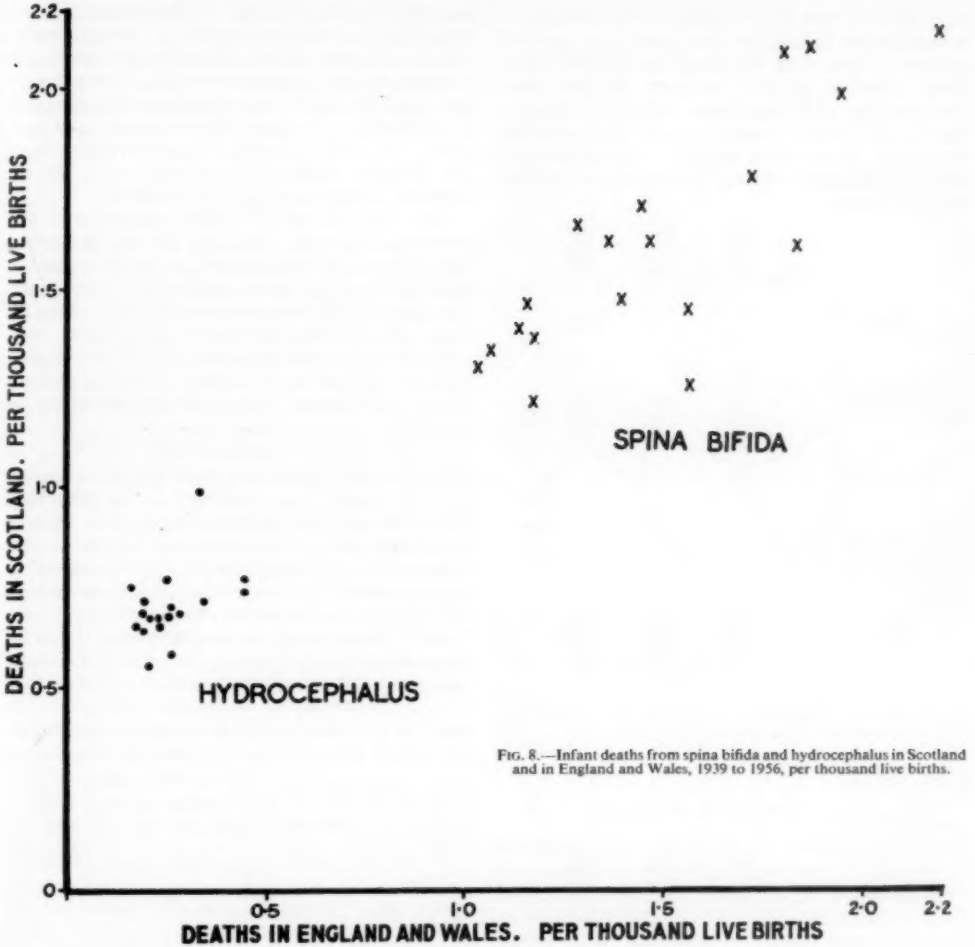

FIG. 8.—Infant deaths from spina bifida and hydrocephalus in Scotland and in England and Wales, 1939 to 1956, per thousand live births.

and Wales in the years 1939–1956 for spina bifida and hydrocephalus (Fig. 8). It is remarkable that while the variations in spina bifida were very similar, the variations in hydrocephalus appear to be almost independent, and with the exception of the three obvious outliers, which represent the years 1940, 1941, 1942, the figures for the remaining years appear quite unrelated. The incidence of infant death from hydrocephalus is about three times as high in Scotland as in England and Wales. It appears that the majority of cases of spina bifida are conditioned by some environmental agent varying concordantly on both sides of the border.

SEASONAL VARIATION

A pronounced seasonal variation in the incidence of anencephalus, the winter incidence being about a third as great again as the summer incidence, has already been demonstrated on the Scottish data in confirmation of a similar variation observed in Birmingham (McKeown and Record, 1951). Analysis of the data for Scotland since published shows an identical trend, and confirms the absence of any seasonal variation in incidence in spina bifida or hydrocephalus.

A more exacting analysis may be made by fitting a harmonic curve to the monthly incidence for

each year: in view of the nature of the variation it is appropriate to take the year starting in July and ending in June. The estimated parameters of the fitted curve of relative incidence for the years between July, 1939, and June, 1956, are shown in Fig. 9. The sector in which a point lies represents the month of maximum incidence, and its distance from the centre its seasonal fluctuation in percentage of the mean.

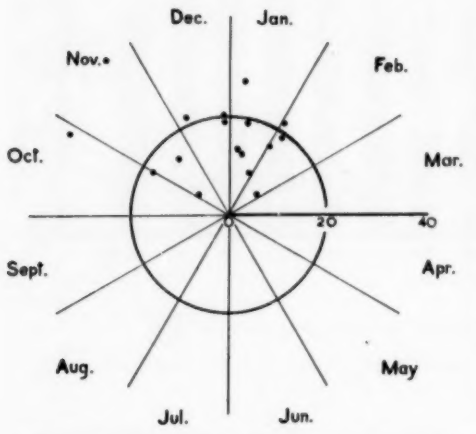

FIG. 9.—Intensity and direction of seasonal variation in anencephalus in Scotland in the period July, 1939, to June, 1956.

SHORT-TERM SECULAR TRENDS

We may examine the short-term distribution of cases with a view to detecting any tendency to "clumping". If any epidemic disorder predisposed to an appreciable proportion of malformations as in rubella and congenital blindness, cases would tend to occur in short bursts, although the combination of many small epidemics might conceal this. On the other hand, any sufficient determinant of a genetic nature, or a predisposition related to some constant environmental feature or to some endemic infection, would be expected to lead to a random distribution of cases in time. The seasonal variation in incidence of anencephalus is consistent with its being related to some epidemic commoner in the spring and summer months, but there is no notifiable disease with a seasonal distribution consistent with this. The principle of the analysis following may be evident if we consider a hypothetical example. Suppose we have data on the number of cases of some malformation in some area with a constant number of births over a period of years. If we consider the mean and variance of the numbers per year, the expected values of the mean and variance would be equal if there were no association between individual cases, but, in the presence of any determinants of an epidemic nature, the expected value of the variance would exceed that of the mean.

The result of this test is not suggestive of any clumping of cases. Analysis of the space-time matrix for cases of anencephalus in the regions of Scotland over the 7-year period 1950–1956, ignoring the areas with very low frequencies, leads to the result $\chi^2 = 283$ for 282 degrees of freedom.

However, visual examination of the figures appears suggestive of erratic variation beyond chance expectation. In Banff, for example, the series:

2, 1, 1, 8, 1, 1, 0

occurs, and suggests that there might be an occasional predisposing infection in addition to a fairly constant basic incidence. A form of analysis more appropriate to occasional epidemic disturbances is to consider the extent by which the largest number of cases exceeds the average during the period of observation. We may make a provisional investigation on the raw figures, assuming a constant number of births per year. If we represent the series in ascending order

$$n_1, n_2, \ldots\ldots n_7$$

then, in the absence of any epidemic disturbance, the square roots of these numbers (or, for a more exact approximation, the transformation $\sqrt{n+\frac{3}{8}}$) will be distributed as random samples from a normally distributed population with variance $\frac{1}{4}$.

If we take x_m as $\sqrt{n_7}$, where n_7 is the largest number, and $\bar{x}$ as $\frac{1}{7}(\sqrt{n_1}+\sqrt{n_2}\ldots\sqrt{n_7})$, we may make use of tables of the distribution of the studentized extreme deviate (Nair, 1948), which gives the tails of the probability distribution

$$\frac{\bar{x}-x_m}{\sigma}.$$

A use of this test shows no suggestion of clumping; out of 45 areas in which more than ten cases occurred, in only one area was the result highly significant (Banff) and only in one other area was it significant. Although we should be cautious in assuming the superiority of such tests over unaided judgment, it appears reasonable to suppose that any infectious non-endemic condition relative to the areas and times studied is unlikely to be a determinant of any considerable proportion of cases.

Similar analyses for spina bifida showed only one area to be significant, and for hydrocephalus, none. In each case, because of the smaller numbers, even greater caution is necessary in taking absence of statistical significance as evidence against any clumping.

Discussion

We may first summarize, in diagrammatic form, the sources of variation in incidence considered above (Fig. 10). These must be regarded as based on the margins of a multidimensional contingency table. The extent to which such studies allow inferences to be made about the body of the table is questionable as there is no unique body for any set of marginal totals. Multiple regression methods are sometimes recommended in these situations but their use is only justifiable if sufficient is known to justify the extensive assumptions on which they are based.

In all three malformations, the influence of the environment is so great that it is reasonable to doubt whether the disorders are genetically determined except in the essentially trivial sense that in such a fragile situation as the developing embryo the initial composition of the zygote will obviously be of importance. The available data on these malformations do not allow any inference that they are genetically determined in the sense that not more than a small proportion could be prevented by changing the environment within the framework of its present variation.

While it is becoming usual to regard an unexplained disease with a familial incidence as genetically determined, such conventions as monogamy and non-communal feeding do not allow the inference that familial disorders are decided at conception. At the present time the evidence for genetic determinants of the major congenital malformations is considerably less than the evidence which could have been advanced 50 years ago purporting to show that rickets was genetically determined.

Social Class.—The most remarkable variations relate to social class. Environmental variations of this magnitude must be suspected as an adequate cause of the familial tendencies of these conditions in the absence of any other evidence of genetic predisposition. The very low incidence in wives of men whose occupation allows them the status of Social Class I, in conjunction with the considerable variation in the immediate and past environment

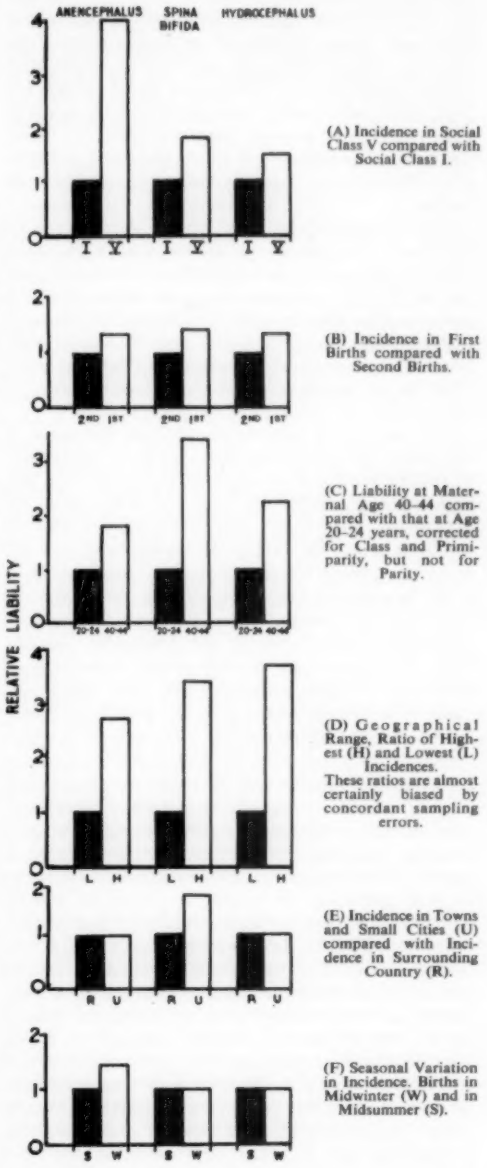
ANENCEPHALUS
SPINA BIFIDA
HYDROCEPHALUS
RELATIVE LIABILITY
I V
2ND 1ST
20-24 40-44
L H
R U
S W
(A) Incidence in Social Class V compared with Social Class I.
(B) Incidence in First Births compared with Second Births.
(C) Liability at Maternal Age 40–44 compared with that at Age 20–24 years, corrected for Class and Primiparity, but not for Parity.
(D) Geographical Range, Ratio of Highest (H) and Lowest (L) Incidences. These ratios are almost certainly biased by concordant sampling errors.
(E) Incidence in Towns and Small Cities (U) compared with Incidence in Surrounding Country (R).
(F) Seasonal Variation in Incidence. Births in Midwinter (W) and in Midsummer (S).

Fig. 10.—Summary of certain environmental influences of the relative liability of still-birth from malformations of the nervous system.

of such women, suggests that a group of women might be specified in relation to their environment who had very low risks of producing a malformed child and almost no risk of an anencephalic. The relatively high maternal age and the high proportion of first births typical of this class make the advantages this environment confers even more remarkable, and any genetic predisposition to these malformations appears to be of the same order of controllability as predispositions to rickets or obesity.

Coffey and Jessop (1957) have shown that in Dublin it is possible to define groups by such criteria as a low haemoglobin, a low plasma protein level, or an unemployed husband, in which the risk of an anencephalic birth exceeds 1 per cent. In Aberdeen, Anderson, Baird, and Thomson (1958) have shown on small numbers that anencephalus may be as common as this in short women of Social Class V.

The nature of this environmental influence is not clear. In view of the low incidence of anencephalus in France (Penrose, 1957) and the relatively high incidence in Rhode Island, U.S.A., some explanation other than generalized impairment in nutrition seems necessary. In Birmingham, an extremely detailed survey of the maternal environment in relation to work during pregnancy in six categories, occupation of husband by fourteen categories, and of rent by ten categories (Record and McKeown, 1949) was not suggestive of even the mildest association of these indices of class with malformation of the central nervous system taken together.

LEGITIMACY.—While the data are not suggestive of any considerable and consistent difference in risk in spina bifida or hydrocephalus, there is strongly suggestive evidence that anencephalus is relatively less frequent in illegitimate births particularly if allowance is made for class and parity. The interpretation of the relative hazards of illegitimacy is difficult; mothers of illegitimate babies include a majority of young primiparae spread among all social classes, and a minority of women whose age and parity status do not differ grossly from those of married women, and whose living conditions tend to be bad. The high proportion of primiparae of the former, and the poor circumstances of the latter, might be expected to lead to a high incidence of all three types of malformations. From these data it appears that ineffectual attempts at abortion could not be responsible for more than a very small proportion of C.N.S. abnormalities of the central nervous system.

PARITY.—The only safe inference which can be made from the Scottish data relate to the relative risk of primogeniture, and this is considerable in all three malformations. In anencephalus the various features of the secular trends in first and other births suggest that this increased risk in primogeniture may be in part due to a distinct condition, with a lower sex-ratio, to which spring and summer conceptions of primiparae are peculiarly but erratically predisposed. The data for spina bifida and hydrocephalus are too limited to allow any breakdown.

This primogeniture effect can only be interpreted as implying that the uterine environment in the few weeks after fertilization differs sufficiently between first and second pregnancies to reduce the risk of the zygote maturing with a malformation of the central nervous system by about one-third.

MATERNAL AGE.—In spina bifida and hydrocephalus, the considerable proportions surviving birth, and the probability that they are influenced by maternal age, prohibits any accurate assessment from data restricted to stillbirths of the increased risks associated with maternal age. While the increased hazards of birth with increasing maternal age must exaggerate these trends they can hardly be sufficient to explain them.

In anencephalus, although the infrequency of surviving birth makes this a trivial source of bias, it remains a possibility that, if the body of the age-parity table were known, the apparent influence of maternal age would merely reflect a parity effect.

The data for maternal age also give the sex of the stillbirth: an efficient test for trend was not suggestive of any tendency for the sex-ratio to be influenced by maternal age. In view of the sampling errors involved (if we assume a hypothetical infinite universe), this is not inconsistent with the lower proportion of males in firstborn anencephalics in Birmingham (MacMahon and McKeown, 1952).

REGIONAL VARIATION.—The way in which a study of the regional variations of congenital disorders may assist in understanding their aetiology is most easily considered by analysing the variations expected on certain assumptions.

First, in a disease the incidence of which varies if the same genotypic group is exposed to various environments, as in silicosis or typhoid, a study of those areas where the disease is very common and very rare may enable relevant differencies in the environment to be inferred. In addition, high correlation between various groups of diseases, as

between chronic bronchitis and carcinoma of the stomach (Stocks, 1947), gives strong evidence that there are some environmental hazards common to both conditions.

Secondly, in a disease peculiarly common in certain genotypic groups, a study of the regional range may suggest some racial proclivity not completely blurred by intermarriage. For example, a subgroup of invaders, colonists, or immigrants may be peculiarly susceptible to some disorder, as Cypriots to thalassaemia, and areas of high incidence may merely reflect a disproportionate ancestry from these sources. While it is difficult to unravel the past, a variable and uncorrelated proportion of different disorders by area is inconsistent with any two of these disorders being strongly predisposed to as a result of the same genetically determined proclivity.

The regional pattern shows that an area with a high incidence of any one of the three major malformations of the central nervous system tends to have a high incidence of both the others, and that the association between anencephaly and spina bifida is particularly high. These associations reflect those found if the scale of the map is increased so that the single family becomes the unit (Penrose, 1946; Record and McKeown, 1950; MacMahon and others, 1953).

In neither case is it permissible to assume that these various deformities are end-results of similar initial disturbancies, as they may result from independently acting agencies which are correlated. The independence of the secular variations in these conditions very strongly suggests that they are largely determined by distinct influences.

The only inferences which can be made from the regional data are that the very considerable variations in the incidence of malformations are to some extent correlated with circumstances predisposing to a high post-neonatal death rate and that in Scotland urbanity does not appreciably influence the incidence of anencephalus or hydrocephalus, but considerably and consistently increases the risk of spina bifida.

SECULAR VARIATION.—The main implications of the secular variation have been discussed above, and may be summarized briefly:

(1) There are considerable variations in annual incidence in all three conditions. These variations are almost independent. In anencephalus, in which the large numbers and high proportion of stillbirths allow a more detailed breakdown, a large part of this variability is due to first births and to winter births: most of this variation could arise from a greatly varying risk to the spring and summer conceptions of nulliparous women.

(2) In anencephalus, but not in spina bifida or hydrocephalus, there is a seasonal trend, the mid-winter rate being about 30 per cent higher than the mid-summer rate.

(3) There is reason to doubt whether any of the three conditions are appreciably influenced by any infections of an epidemic nature. However, statistical methods based on large areas should not necessarily be regarded as superior to intuitive judgments on small areas. An epidemic is only relative to the deme, and a disease can be endemic on a county scale, but epidemic on a village scale. All that can be said of the Scottish data is that, if an infection is involved, it is not epidemic in relation to units of county, large town, or city size.

POSSIBLE ENVIRONMENTAL INFLUENCES.—Penrose (1957) suggested eight groups of enviromental influences as most worthy of consideration in anencephalus, and this survey of the Scottish data may be concluded by considering these:

(1) *Infection.*—The absence of any pronounced tendency to clumping in the time sequence of cases of each malformation, and the absence of any seasonal trend in spina bifida and hydrocephalus, probably excludes epidemic infections as a major cause. Endemic infections cannot be excluded on these grounds. In anencephalus, in which the class gradient makes this explanation attractive, the seasonal trend of greatest risk for early summer conceptions seems an unlikely consequence of an endemic infection in Scotland.

An increased incidence of febrile infections early in pregnancy resulting in anencephalus has been recorded on retrospective inquiry by Coffey and Jessop (1957).

Prospective inquiries relating to pregnancies resulting in any malformation have also shown this (*Bull. Inst. nat. Hyg., Paris*, 1956; MacDonald, 1958). In view of the higher incidence of febrile illness in winter, the absence of any seasonal trend in spina bifida or hydrocephalus, and the relative immunity of winter conceptions to anencephalus, it seems possible that an increased incidence of infection may merely reflect the very poor and overcrowded environments which predispose to these abnormalities.

(2) *Malnutrition.*—This, if used to denote inadequate intake, seems an unlikely factor in Scotland since 1945. There has been no tendency

to a decreasing incidence of malformations of the central nervous system in the last 18 years and there is a very much higher incidence of anencephalus in Great Britain and in Rhode Island than in most of Europe. In addition the class differences are relatively slight between Social Classes III, IV, and V, but considerable between I, II, and III, in contrast with those to be expected from inadequate nutrition.

(3) *Chemical Poisons.*—These appear worthy of serious consideration, particularly in view of the increasing number of preservatives, dyes, and bleaches in common use, and the increasing contamination of foodstuffs with antibiotics, weedkillers, insecticides, and synthetic oestrogens. We may mention some of the more obvious possibilities.

Alcohol can probably be excluded as an important cause because of the nature of the social class gradient, and, in the case of anencephalus, the remarkably low incidence in Stockholm (0·6 per thousand), Paris (0·5 per thousand), and Lyons (0·1 per thousand) (Penrose, 1957).

Tobacco appears to be largely excluded as a major factor by the erratic secular variation. It is not, however, unreasonable to suspect a vasoconstrictor and oxytocic substance as a contributory cause.

Preservatives, Dyes, and "Improvers" in Foodstuffs, which are widely used with no recommendation other than that of being toxic to bacteria or colourful or producing a white frothy bread, are so widespread that, if any were to cause embryonic damage, it would be extremely difficult to detect. The recent history of carcinoma of the lung shows how easily a lethal habit can become adopted, and how, although at least 80 per cent. of cases could be prevented by not smoking, there are remarkable regional variations in incidence due to various interactions. It seems probable that the failure of a quantitative improvement in nutrition to reduce the incidence of foetal deformity is due to independently increasing environmental hazards. Among factory-produced foodstuffs with a class gradient in intake, may be mentioned the colouring matter in margarine, the large number of mixtures which are supplied as dehydrated cakes and pastries, and ice cream. An aversion to foods processed on an industrial scale and a relative conservatism towards some modern farming techniques are possible reasons for the relatively low incidence of anencephalus on the European continent compared with that in such relatively well-fed regions as Great Britain and Rhode Island.

(4) *Hormones.*—The variation in hormone levels is hardly likely to vary so widely by place, time, or social class as the abnormalities of the central nervous system, and it is unlikely that this aspect of the uterine environment could explain more than a small fraction of the variation in incidence. Recently a hormone preparation which disturbs the empty uterus sufficiently to induce menstruation has been widely advertised as a method of diagnosing pregnancy. Although this has not been in use long enough to be relevant to the differences in the years up to 1956, it is the type of insult which is likely to cause foetal malformations, and would often be administered at a stage in pregnancy when it might initiate malformations of the central nervous system.

(5) *Mechnical Trauma* in utero.—Anencephalus and spina bifida are probably determined in the first few weeks of embryonic life. Attempted abortion is unlikely to be a predisposing cause in anencephalus which is less common among illegitimate births. The data on spina bifida are hardly adequate to assess any effects of illegitimacy, but there is nothing to suggest any considerable influence. In hydrocephalus the stage at which the abnormality usually becomes irreversible is unknown: while the available data for 1950–1956 are consistent with an appreciable proportion of hydrocephalics being consequent on attempted abortion, this interpretation is not supported by the more extensive data for the years 1939–1949. Mechanical effects from coitus in the first weeks of pregnancy are hardly likely as an important cause of an abnormality which is almost as common in illegitimate births, and in which the incidence increases with maternal age.

(6) *Radiation Trauma* from diagnostic procedures can clearly be ruled out as a common cause in view of the probable time of the foetal insult. Nevertheless it is of interest to note that, if an *ad hoc* inquiry based on a comparison of malformations of the central nervous system with a randomly ascertained collection of controls were made, the combined influences of primiparity, maternal age, and in the case of spina bifida, of urbanity, might conspire to produce a spurious association with pelvimetry. The association of a small pelvis with low social class might considerably increase the intensity of such an apparent association.

(7) *Foetal Anoxia* is capable of producing many malformations, including those of the central nervous system, in rodents. The common causes of relative maternal anoxia in man are flying in pressurized airliners, winter sports, and general anaesthesia, particularly when casually administered for minor operations. Flying and winter sports could hardly be related to more than a very small proportion of cases, even if they induced sufficient anoxia to be harmful. Anaesthesia in pregnancy is not uncommon because the free dental treatment of adults is restricted to expectant mothers; dental anaesthesia, though brief, is notoriously anoxic. Though this might initiate hydrocephalus and some other malformations, it is usually administered too late in pregnancy to influence the development of either anencephalus or spina bifida.

(8) *Climatic Anomalies* appear unlikely to have much influence. The incidence of anencephalus seems to be higher in the moderate climate of Scotland than in Scandinavia or central Europe. Spina bifida and hydrocephalus show no seasonal variation.

SUMMARY

The endemiology of the common malformations of the central nervous system (anencephalus, spina bifida, and hydrocephalus) is discussed on the data of the Registrar General for Scotland.

It is concluded that:

(1) In all these conditions there is a marked association with social class.

(2) Anencephalus is relatively uncommon in illegitimate pregnancies: the incidence of spina bifida and hydrocephalus shows no consistent relationship to legitimacy.

(3) All three conditions are about 40 per cent. more common in first births than in second births.

(4) All three conditions become commoner with increasing maternal age. This may however merely reflect an association with parity. Anencephalus and hydrocephalus also appear relatively commoner in the pregnancies of women under 20 years of age.

(5) Each condition shows marked regional variation. Spina bifida, but not anencephalus or hydrocephalus, is consistently and considerably predisposed to by urbanity.

(6) Each condition shows marked, but largely independent, year to year variations. In anencephalus these variations are largely due to the changing incidence in first births, and in winter births. In spina bifida, but not in hydrocephalus, the incidence in Scotland varies concordantly with that in England and Wales.

(7) There is a marked seasonal variation in the incidence of anencephalus but not of spina bifida or hydrocephalus, the peak incidence falling between late October and late February every winter from 1939–1940 to 1955–1956.

(8) There is no evidence of any tendency to "clumping" of cases. This implies that epidemic disorders do not make any important contribution to the incidence of these malformations.

(9) The marked environmental influences cast doubt on the necessity of advancing genetic causes to explain familial concentrations of cases.

(10) The fact that, although the malformations of the central nervous system are more common in less favourable social circumstances, their incidence has not declined during a period when nutrition has improved, suggests other environmental influences have become increasingly important.

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APPENDIX A

Suppose that we have data in the following form for several sets of towns and their surroundings:

	Town	Country
Anencephalic Births	a	b
All Other Births	c	d

Then the relevant estimator of the urbanity effect is of course

$$\frac{a}{a+c} \Big/ \frac{b}{b+d}.$$

It is convenient to use the natural logarithm of this term which has the easily calculated sampling variance (Haldane, 1957):

$$\frac{1}{a} - \frac{1}{a+c} + \frac{1}{b} - \frac{1}{b+d}.$$

By weighting the estimate for each set by the inverse of its variance (i) we should obtain an efficient estimate of this urbanity factor if it were constant from area to area. The estimators:

$$\log_e \frac{a+\frac{1}{2}}{a+c+\frac{3}{4}} \Big/ \frac{b+\frac{1}{2}}{b+d+\frac{3}{4}}, \text{ with variance}$$

$$\frac{1}{a+1} - \frac{1}{a+c+1} + \frac{1}{b+1} - \frac{1}{b+d+1},$$

have been used in Table VIII in an attempt to reduce bias.

Because of variations from place to place, the direct estimation of the incidence in groups of towns, and of their surroundings, would be fallacious.

APPENDIX B

In the case of the simple harmonic cyclic trend

$$1 + \alpha \operatorname{Sin} (\theta + \varphi)$$

where θ specifies the time of the year, and φ the time of the year of maximum incidence, a simple, approximate, but very efficient method of estimating α and φ, when α is small, is to take the square root of the number of cases arising each month and to take moments about the centre; to a very close approximation we may take θ as 15°, 45°, 75°, etc., for Jan., Feb., March, etc., and assume a constant number of births per month.

It will be shown elsewhere that, given the numbers of events per months as $n_1, n_2, n_3 \ldots n_{12}$, and taking $\theta_1, \theta_2, \theta_3$ as 15°, 45°, 75°, etc., then

$$N = \sum_1^{12} n_1$$

$$W = \sum_1^{12} \sqrt{n_1}$$

$$S = \sum_1^{12} \sqrt{n_1} . \operatorname{Sin} \theta_1$$

$$C = \sum_1^{12} \sqrt{n_1} . \operatorname{Cos} \theta_1$$

$$d = \frac{\sqrt{S^2 + C^2}}{W}, \qquad \alpha \simeq 4d$$

$$\varphi \simeq \tan^{-1} \frac{S}{C}$$

Brit. J. prev. soc. Med. (1958), **12**, 131–134

POST-NEONATAL INFANT MORTALITY IN BIRMINGHAM BETWEEN 1947 AND 1956

BY

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The three main groups of deaths in early life—stillbirths, deaths in the first month, and deaths in the second to twelfth months—have characteristic distributions with respect to birth rank and maternal age. The risk of post-neonatal death is greatest for children of higher birth ranks and this has been especially evident among the later children of young mothers (Elderton, 1928; Gibson and McKeown, 1952; Baird, Thomson, and Duncan, 1953; Heady, Daly, and Morris, 1955).

It seems likely that these effects have been produced in two main ways. First, infections were brought into the household by older children; the birth rank effect was shown to be far greater for infective than non-infective deaths (Gibson and McKeown, 1952). Second, the increased effect of high birth rank when the mother was young suggests that the risk was influenced by factors especially associated with a very early start to child-bearing and with closely-spaced pregnancies, and that analysis in terms of rank and age together reflected a wide range of social circumstances which less directly but no less potently may have influenced the chances of survival.

Since these demonstrations were presented infant mortality has fallen yet further. Much of the continuing fall seems attributable to the prevention and treatment of serious infective illness and this accounts for the disproportionate fall in post-neonatal mortality compared with stillbirths and neonatal death rates. In a time of such rapid change, it is of interest to ask what has been happening to the association between high risks and certain birth rank/maternal age groups and to the separate interactions of the latter with changes in infective and in non-infective death rates. These questions are particularly relevant at the present time because the incidence of infective deaths is now so low that we must expect a deceleration in the very rapid decline of overall mortality which has been attributed to their control, and there are in fact indications that this has already begun.

The general purpose of the present study is to examine the changes that have taken place in Birmingham in the decade 1947 to 1956 and to interpret them against this background. Its particular objects are:

(1) to enquire to what extent the association between infant mortality and birth rank and maternal age has altered since 1947;

(2) to examine the changes in post-neonatal mortality classified according to cause.

Material

This examination is based upon analyses by birth rank and maternal age of live births to residents of the City of Birmingham and the children who were known to have died in their second to twelfth months. Dates refer to the year of birth whether death occurred in that year or in the following year.

The full data for 1947 and the live-birth data for 1950 and 1953 have already been published (Gibson and McKeown, 1952; Padley and Taylor, 1952, Padley and Neale, 1954); the live-birth data for 1951, 1952, and 1954 to 1956 were supplied by the Central Statistical Office of the City of Birmingham, but data for 1948 and 1949 were not readily available and these years have been excluded. The data relating to the deaths in the years 1950–1956 were obtained by analysis of existing Maternity and Child Welfare records for these years.

The birth rank statistic used is the number of previous live births: 0; 1; 2; and 3 or more. The mother's age at the time of birth is also used in a

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condensed form with three groups of approximately equal size: under 25 years; 25 to 29 years; and 30 or more years. Rates are given as deaths per related 1,000 live births.

Causes of death are based upon the death certificates and are broadly grouped as follows:

(1) Infective causes (mainly pneumonia, bronchitis, gastro-enteritis, infectious fevers, tuberculosis and meningitis; convulsions have also been classed as infective);

(2) Non-infective causes (mainly malformations, accidents and neoplasms);

(3) Indeterminate causes (for example atrophy, debility, prematurity, cirrhosis, "nephritis").

Results

Tables I and II show the distribution according to birth rank and maternal age of the 128,496 infants born alive in the period 1950 to 1956, and of the 1,030 related post-neonatal deaths.

TABLE I

NUMBERS OF LIVE BIRTHS ACCORDING TO BIRTH RANK AND MATERNAL AGE: BIRMINGHAM 1950–56

Previous Live Births	Maternal Age (yrs)			Total
	Under 25	25–29	30 and Over	
0	26,154	14,040	8,039	48,233
1	10,099	13,777	12,475	36,351
2	2,901	7,015	10,138	20,054
3 and Over	1,003	5,517	17,338	23,858
Total	40,157	40,349	47,990	128,496

TABLE II

NUMBERS OF POST-NEONATAL INFANT DEATHS OF CHILDREN BORN IN 1950–56 ACCORDING TO BIRTH RANK AND MATERNAL AGE

Previous Live Births	Maternal Age (yrs)			Total
	Under 25	25–29	30 and Over	
0	165	61	38	264
1	114	82	78	274
2	44	81	55	180
3 and Over	28	100	184	312
Total	351	324	355	1,030

Table III gives the distribution of death rates derived from the first two tables, and it is at once evident that the birth rank/maternal age pattern demonstrated in 1947 (Gibson and McKeown, 1952) was still present in 1950–56.

The main features of this pattern are a moderate reduction in mortality with increasing maternal age, a more marked increase in mortality with increasing birth rank, and a very distinct interaction between the two factors producing the pattern expressed in Fig. 1 (opposite).

TABLE III

POST-NEONATAL DEATH RATES (PER 1,000 LIVE BIRTHS) ACCORDING TO BIRTH RANK AND MATERNAL AGE: BIRMINGHAM 1950–56

Previous Live Births	Maternal Age (yrs)			Total
	Under 25	25–29	30 and Over	
0	6·3	4·3	4·7	5·5
1	11·3	6·0	6·3	7·5
2	15·2	11·5	5·4	9·0
3 and Over	27·9	18·1	10·6	13·1
Total	8·7	8·0	7·4	8·0

The stepped lines divide this Table into three parts: the upper right portion with a relatively low mortality rate will henceforth be referred to as Zone I, the lower left part with a high mortality rate as Zone III, and the intermediate region as Zone II.

It may be represented as a low incidence zone (Zone 1) including the first babies of mothers under 25 years, the first and second babies of mothers aged 25 to 29 and the first, second and third babies of mothers aged 30 or over, together with zones of greater risk (Zones II and III) at successive higher ranks. The highest rate for a single birth rank/maternal age group is about six times the lowest, and even the three broad zones indicated in Table III exhibit successively a doubling and trebling of the lowest rate. Viewed in terms of age-cohorts, this represents high mortalities among the subsequent babies of mothers who first became pregnant at early age and/or those whose successive pregnancies closely followed each other.

Table IV gives an analysis of the secular trend of the post-neonatal mortality rate according to maternal

TABLE IV

POST-NEONATAL INFANT MORTALITY RATES (PER 1,000 LIVE BIRTHS) AT DIFFERENT BIRTH RANKS AND AT DIFFERENT MATERNAL AGES ACCORDING TO YEAR OF BIRTH

Year of Birth	Maternal Age (yrs)			Total Mortality	Previous Live Births			
	Under 25	25–29	30 and Over		0	1	2	3 and Over
1947	20·4	17·6	15·3	17·6	11·5	17·4	22·7	27·9
1950	9·4	9·2	10·3	9·7	6·6	7·4	10·6	19·4
1951	9·1	11·5	8·3	9·6	6·2	8·1	8·5	19·7
1952	9·1	6·5	8·3	8·0	5·8	6·5	11·2	12·0
1953	8·8	8·2	5·2	7·3	4·5	8·1	9·4	10·0
1954	8·3	5·4	6·7	6·8	5·5	5·8	8·5	9·4
1955	8·2	5·9	6·1	7·3	4·1	9·1	6·4	11·0
1956	8·3	6·9	7·0	7·4	5·6	7·7	8·2	9·9

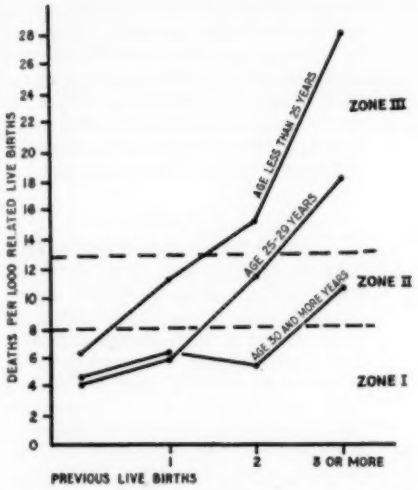

FIG. 1.—Post-neonatal mortality rates by birth rank at different maternal ages, Birmingham, 1950–56

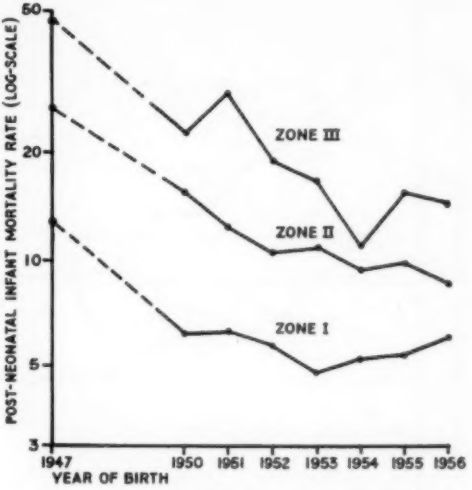

FIG. 2.—Post-neonatal mortality trends in different Birth Rank/Maternal Age zones.

age and according to birth rank. The total rates for each year (centre column of Table IV) show a tendency for the declining rate to level off. It is also evident from Table IV, as well as from the first panel of Table V, that the fall in mortality over ten years has affected all groups of children but that it has been proportionately greater in the groups where it was and still is the highest (see Fig. 2). Since 1950, indeed, mortality from all causes in Zone I has been virtually static. The total picture then is of a heterogeneous population, one part of which has already reaped most of the rewards of the current phase of declining mortality and the other part of which, still with some distance to go, nevertheless is catching up and causing some narrowing of differentials.

Table V also gives an analysis of infective and non-infective mortality rates between 1947 and 1956 and confirms that their relative proportions have changed. Infective deaths showed a steady if decelerating fall while non-infective deaths did not change much over the ten years, falling a little at first and rising again later. The centre panels of Table V supply the detail that the infective mortality fell somewhat faster in Zones II and III than in Zone I and resulted towards the end of the period in some narrowing of the difference between them (see also Fig. 3, overleaf).

It is also clear that the zonal differential is as consistent from year to year in the non-infective mortality as it is for the infective deaths and proportionately is not much less. This perhaps is an

TABLE V

POST-NEONATAL INFANT MORTALITY RATES ACCORDING TO CAUSE IN DIFFERENT BIRTH RANK/MATERNAL AGE ZONES

Year of Birth	Zone I Total	Zone II Total	Zone III Total	Zone I		Zones II and III		All Births	
				Infective	Non-Infective	Infective	Non-Infective	Infective	Non-Infective
1947	12·1	25·7	47·4	9·0	3·1	25·5	4·3	14·2	3·4
1950	6·2	15·4	22·6	4·0	1·5	12·3	3·7	6·7	2·2
1951	6·3	12·3	29·4	3·4	1·7	10·2	4·6	5·7	2·7
1952	5·7	10·5	19·0	3·5	1·9	7·7	3·1	4·9	2·3
1953	4·8	11·0	16·7	3·3	1·0	7·6	4·0	4·7	2·0
1954	5·3	9·4	11·0	2·6	2·0	5·3	2·7	3·5	2·3
1955	5·4	9·8	15·6	2·7	2·2	5·3	5·1	3·6	3·1
1956	6·0	8·6	14·4	2·5	2·9	5·0	3·6	3·4	3·1

Discrepancies between totals and the sum of infective and non-infective rates are due to omission from this table of deaths from indeterminate causes. These amount ot one-tenth of all the deaths (103 of the 1030).

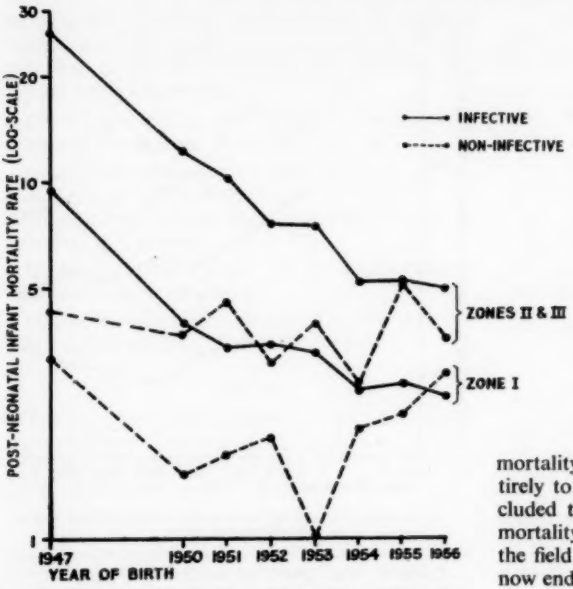

FIG. 3.—Post-neonatal mortality according to cause in different Birth Rank/Maternal Age zones.

indication of the importance of indirect social factors in the determination of the birth rank/maternal age differences in overall mortality.

Yet, despite the importance of such factors in determining the death rates both from infective and non-infective illness, one group has declined in frequency and the other has not. Moreover, the reduction of social differentials over the ten years, though present, was not impressive. We must conclude that the main improvements of the last decade were due to causes not correlated with the social differences expressed in the birth rank/maternal age analysis and that the wide use of antibiotics and other modern treatments probably played a much greater part than any narrowing of these differences. This all lends force to the view that the recent rapid improvements are now coming to an end and that future advances will depend increasingly upon improved fundamental understanding of non-infective diseases, and the means of preventing and treating them, and upon attention to those social factors which still maintain the mortality differences between different groups.

SUMMARY

The birth rank/maternal age distribution of post-neonatal infant mortality rates in Birmingham in 1947 is shown to have persisted over the following ten years despite a large overall reduction and a small degree of narrowing of the differentials. Although these differentials were as consistent for non-infective as for infective deaths the reduction of mortality over these ten years has been due entirely to a reduction in the latter group. It is concluded that the recent period of rapidly declining mortality was due mainly to therapeutic advances in the field of infective disease and that this period is now ending.

The authors gratefully acknowledge their indebtedness to Dr. Enid Charles who designed the original records, to Dr. Richard Padley who succeeded Dr. Charles as Chief Statistical Officer, Birmingham, during the period 1953–1957, and to Mr. A. B. Neale, Corporation Statistical Officer. We should also like to express our thanks to Dr. Matthew Burn and the members of his staff for their cooperation.

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TUBERCULOSIS IN IMMIGRANTS IN BIRMINGHAM, 1956–1957

BY

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Until quite recently the only numerically important migration into Great Britain was from Ireland, and the two papers (Hess and Macdonald, 1954; Brett, 1958) published since 1945 on tuberculosis in immigrants dealt mainly with tuberculosis in Irish immigrants to one section of London. The City of Birmingham, with a population of just over 1,100,000 has many inhabitants who are not natives of the city; most have come from other parts of England, but there has also been for many years a steady immigration of Irish, and for a rather shorter period a number of Indians and Pakistanis and a considerable influx of West Indians. With this varied population and a unified tuberculosis service, it seemed appropriate to undertake at least a preliminary study of tuberculosis in immigrants in Birmingham.

It was accordingly arranged that tuberculosis visitors should routinely ascertain the place of birth of every person notified as suffering from tuberculosis in Birmingham on and after January 1, 1956.

From the information so obtained it has been possible to tabulate the place of birth, age, and sex of persons notified during the years 1956–57. It was apparent from a preliminary tabulation of the 1956 notifications that two immigrant groups, Irish and Asian born, were large enough to justify further study. The case-records of as many as possible of these patients were therefore studied to extract further information concerning date of entry to this country, type of disease, and bacteriological state. Although the cases of tuberculosis among West Indians were not numerous their records were similarly analysed, using both 1956 and 1957 cases to increase the size of the group.

Place of birth was selected as the criterion for study because the Census reports give sub-divisions of population by place of birth, and the census information is used as the basis for estimating the Irish born population of Birmingham, and for one estimate of the Asian born. For a second estimate of the Asian population and the only available estimate of the West Indian born population, we are indebted to Mr. A. Gibbs, Liaison Officer for Coloured People, City of Birmingham.

1956–1957 Notifications by Place of Birth

Table I shows separately for 1956 and 1957 the numbers of persons notified as suffering from tuberculosis according to their place of birth. Notifications were 14 per cent. less in 1957 than in 1956, but with two exceptions the distribution by place of birth is very similar in the two years. The most important difference is the increase in the proportion recording Asian birth from 4·3 per cent to 7·6 per

TABLE I

PLACES OF BIRTH OF BIRMINGHAM RESIDENTS NOTIFIED AS SUFFERING FROM TUBERCULOSIS IN 1956–1957

Place of Birth		Year	
		1956	1957
Great Britain	England	890	660
	Wales	20	18
	Scotland	20	12
	Total	930	690
Ireland		127	128
Asia	India/Pakistan	42	62
	Aden	4	8
	Other Asian	3	4
	Total	49	74
West Indies		9	12
Miscellaneous and Not Known	Europe, excluding British Isles	14	12
	America, excluding West Indies	1	2
	Africa	5	4
	Not Known	1	51
	Total	21	69
Grand Totals		1,136	973

cent, with an increase in actual numbers from 49 to 78. The second difference of importance is the appearance of a group of about 5 per cent. of the total in 1957 for whom the place of birth is "not known". 1956 was the first year in which this information was collected, and it seems probable that the field-workers and clerical staff responsible were anxious to make as complete a record as possible and supplied the most probable answer when definite information was lacking. When the apparent completeness of the results became known at the end of the year, it was made clear that in subsequent years, including 1957, place of birth was to be recorded only when the information was positively available. The accuracy of the returns for the major immigrant groups (Irish, West Indian, Asian) in 1956 has been checked by subsequent studies of the medical notes and further inquiries where necessary, so that over-estimation of these groups is not possible in that year. The corrections made as a result of studying the case records, sometimes supplemented by further questioning of the patient, account for the small differences between Table I and the figures published in the report of the Medical Officer for Health for 1956.

Table I shows, as noted above, that, apart from the native born English group, the only group with large enough numbers for further study are the Irish and Asian (especially Indian/Pakistan) places of birth. The West Indians were studied as a separate group despite the small number of cases. The very small numbers recording Welsh or Scottish places of birth have been combined with those of English birth: all others and those not recorded have been taken as a final heterogeneous group.

Table II records for each of these five birth-place groups the age-sex distribution of the persons notified as suffering from tuberculosis in the years 1956–7 taken together.

As would be expected, the number of children under 15 years of age with foreign places of birth is very small indeed, and even up to age 20 years the numbers are small in the immigrant groups. The majority of notifications in immigrants occur amongst adults, and mainly amongst adults under the age of 55 years. While the notifications of those born in Ireland or the West Indies show very much the sex distribution of the native born, there are very few females amongst those recording Asian birth; at least one of the three was in fact of European parentage.

Population Estimates

Irish Born.—At the time of the 1951 Census there were 20,033 males and 16,316 females resident in the City of Birmingham who recorded an Irish place of birth, a total of 36,349. The figure for the county of Warwickshire (including Birmingham) was 43,575, compared with 10,946 in the County at the 1931 Census. If the proportion of all in the County who live in the City has been constant, this suggests an annual increase of about 1,400–1,500 in the Irish born population of the City if the increase is evenly spread over the 20-year period. It is more probable that the increase was accelerated during the war

Table II

AGE-SEX DISTRIBUTION OF PERSONS NOTIFIED IN 1956–7 BY PLACE OF BIRTH

Place of Birth	Sex	Age (yrs)								Total
		0–	15–	20–	25–	35–	45–	55–	65 and Over	
Great Britain	Males	145	79	102	101	140	172	148	74	961
	Females	176	78	101	134	78	43	21	28	659
Ireland	Males	5	5	34	52	29	18	5	4	152
	Females	5	6	37	37	13	4	1	0	103
Asia	Males	1	0	14	51	34	17	3	0	120
	Females	1	1	0	1	0	0	0	0	3
West Indies	Males	0	0	4	8	2	2	0	0	16
	Females	0	0	0	2	3	0	0	0	5
Miscellaneous and Not Known	Males	3	1	2	22	9	5	8	4	54
	Females	2	6	6	13	4	1	2	2	36
Totals	Males	154	85	156	234	214	214	164	82	1303
	Females	184	91	144	187	98	48	24	30	806

years and after, suggesting an increase of at least 2,000 per annum. If this has been continued since 1951 for a further 5 years there will have been a further increase of 10,000 to a total of 46,000 Irish born in 1956, and certainly 45,000 would seem the lowest likely estimate of the Irish born population in 1956–7. It is difficult to arrive at an upper limit for the Irish born population in 1956–7, but in view of the earlier rate of growth it seems unlikely to have more than doubled in 5 years after the 1951 Census, *i.e.* 72,000 is a probable upper limit, with a total Irish born population of between 50,000 and 60,000 as reasonably likely for 1956–7.

ASIAN BORN.—At the 1951 Census, 2,581 males and 1,128 females resident in the City of Birmingham recorded Asian (mainly Indian/Pakistan) places of birth, a total of 3,709. The number of Asian males will certainly have increased since then, but probably not by a factor of more than 2 or 3, suggesting 5,000–7,500 males and 1,000–2,000 females of Asian birth in the City in 1956–7.

The Liaison Officer for Coloured People estimates the total population of Asian descent of adult ages at 8,000–11,000 in 1956–7. He regards 12,000 as an absolute upper limit to the number of adult Asian males in the City at the end of 1957.

WEST INDIAN BORN.—There were less than 500 individuals born in the West Indies in Birmingham in 1951, but from 1954 there has been a considerable immigration of West Indians into Birmingham, as into many other areas. The Liaison Officer for Coloured People estimates their number during 1956–7 in the City of Birmingham as 20,000–25,000 and certainly not less than 20,000 at the end of 1957.

NOTIFICATIONS RELATED TO POPULATION ESTIMATES

The estimates of population by places of birth are subject to such large errors that it seems impracticable to calculate notification rates from them. The notification figures are known precisely, and for age and sex groups, and from these figures calculations have been made of the population from which they would have been drawn had all racial groups in the City experienced the same notification rate and using the age-sex distribution of population for Birmingham at the 1951 Census. For example, there were 81,500 males aged 25–34 in the City at the 1951 Census, and there were 234 notifications of males of this age in 1956–7, so that for this age-sex group there was one notification for every 371 of the population: the 52 notifications for Irish males of this age group might reasonably be drawn from a population of 19,450. Similar calculations have been made for all other age and sex groups, and the figures so obtained are compared with the population estimate from other sources in Table III.

TABLE III

IMMIGRANT POPULATION RELATED TO POPULATION EXPECTED FROM NOTIFICATIONS

Place of Birth	Probable Population in 1956–7 (*a*)	Population from which 1956–7 Tuberculosis Notifications would be Expected (*b*)	Ratio *b* : *a*
Ireland ..	45,000–70,000	109,000	2 : 1
Asia ..	8,000–11,000	45,000	6 : 1 to 4 : 1
West Indies	20,000–25,000	9,000	1 : 2 to 1 : 3

These comparisons suggest that the notifications received for Irish and Asian born groups were in excess of what would be expected, by a factor of about 2 for the Irish born and of between 4 and 5 for the Asian born. Although the population estimates are subject to such large errors it seems fairly certain that there is an excess of notifications in these two groups, much greater in the case of the Asian group than the Irish.

There is no evidence at all of any excess of notifications amongst the West Indian group and indeed their notifications are rather less than might be expected. Again, even allowing for gross errors in the population estimates, it seems quite certain that there is no evidence of any excess of notifiable tuberculosis amongst the West Indians in Birmingham in the years under review.

There is another way of looking at the excess of notifications in the Irish and Asian born groups. The Irish notifications are about double what might be expected, and total 128 per year: this suggests that at the present time the Irish contribute about 65 excess notifications per year. The Asian notifications are about five times the expected number, with an annual average of just over sixty, suggesting about fifty excess notifications each year. These two groups together contribute an excess of about 115 cases, or about 10 per cent. of the total notifications each year.

ANALYSIS OF CASES OCCURRING IN THE IRISH, ASIAN, AND WEST INDIAN BORN

Tables IV to VI (overleaf) give results of further study of the cases notified from these groups. In four patients, the original diagnosis of tuberculosis has

since been revised; for a further eight no information other than the fact of notification is available—four Irish and four Asian. There remain 73 Irish males, 48 Irish females, 43 Asian males, and twenty West Indians with a confirmed diagnosis of tuberculosis; in nine males and six females from Ireland, in seven Asians, and in six West Indians the disease was non-respiratory, *i.e.* one in eight Irish and one in six Asians had non-respiratory tuberculosis, as against almost one in three of the West Indians, suggesting that disseminated lesions occurred in a higher proportion of the last-named group.

TABLE IV

FURTHER CLASSIFICATION OF DIAGNOSIS OF CERTAIN BIRTH-PLACE GROUPS

Year of Notification	1956			1956–7
Place of Birth ..	Ireland		Asia	West Indies
Sex	Males	Females	Males	Males and Females
Diagnosis Revised, Non-tuberculous	1	1	1	1
Non-Respiratory Tuberculosis	9	6	7	6
Respiratory Tuberculosis	64	42	36	14
No Information	3	1	4	0
Totals	77	50	48	21

Table V gives a broad classification of the type and extent of disease in those with respiratory tuberculosis. The West Indians had a high proportion (one in two) with pleural effusion or hilar gland enlargement, which may reasonably be taken to indicate recent primary infections, and is in keeping with the high proportion of disseminated lesions in this group; in the other groups studied the proportion of respiratory cases with pleural effusion or hilar gland enlargement varies between one in five and one in eight. Even on the small total, the distribution of the West Indian cases is in this respect significantly different from that of any of the other three groups. Males and females of Irish birthplace have a reasonably similar distribution by type and extent of disease, but the Asians show a relatively small number with cavitated disease and a correspondingly large proportion with disease of limited extent, involving one zone or less.

Table V shows also the number known to have a positive sputum in each group. In the West Indians and Asians, less than half, and in Irish females about half of the respiratory cases had a positive sputum, and in the Irish males about two-thirds had a positive sputum; no information is available concerning just over half of the remainder (usually because of early return to Ireland).

Finally, in Table VI, the available information concerning the time interval between entry to this country and notification is recorded for the respiratory cases, but with rather large numbers for which this information is not available. The Irish cases had in general been in Great Britain for some time before notification; more than one in three had been in Great Britain for over 5 years, and there is

TABLE VI

DURATION OF STAY IN ENGLAND BEFORE NOTIFICATION

Year of Notification		1956			1956–7
Place of Birth ..		Ireland		Asia	West Indies
Sex		Males	Females	Males	Males and Females
Duration of Stay (yrs)	–1	7	6	10	3
	–2	7	9	5	2
	–3	6	5	6	4
	–5	12	2	6	2
	–10	11	8	4	1
	>10	12	11	1	1
	Not Known	9	1	4	1
Totals		64	42	36	14

TABLE V

RADIOLOGICAL TYPE AND EXTENT OF DISEASE AT NOTIFICATION (RESPIRATORY CASES)

Year of Notification			1956			1956–7
Place of Birth			Ireland		Asia	West Indies
Sex			Males	Females	Males	Males and Females
Extent of Disease	Pleural Effusion		6	9	4	6
	Hilar Glandular Enlargement		2	0	2	1
	No Cavity	1 zone only	10	7	14	1
		>1 zone	14	12	12	3
	Cavitated		32	14	4	3
	Total		64	42	36	14
Known Sputum Positive			46	20	15	5

no tendency for an accumulation of cases to occur in the first year or two after arrival; no males but three females were notified within three months of arriving in this country.

In both the Asian and West Indian groups the duration of stay in this country before notification is in general less, and a very high proportion of cases are notified within three years of arrival; this probably reflects in both groups, but especially in the West Indians, the fact that immigration of the whole group from which they are drawn is comparatively recent. However, there are differences between the Asian and West Indian groups: no West Indians were notified with three months of arrival, whereas four Asians were notified within that time, three of them with positive sputum at diagnosis; it seems reasonably certain that in these at least the disease must have been present on entry, and in these three cases the intervals between entry and *x* ray were 1 week, 1 month, and 3 months.

Discussion

Hess and Macdonald (1954) based their study of tuberculosis in Irish immigrants on patients in five major hospitals in North-West London, a method which they realized might be subject to considerable selective factors. Their general conclusion was that the ratio of Irish patients to London patients was at least three times that expected, and attributed this mainly to the movement of a susceptible, non-infected rural population into a relatively infectious urban environment.

The present study confirms that there is more tuberculosis among the Irish born population than in the Birmingham population as a whole, but suggests that the notifications are about twice as numerous as would be expected for the general population. The factor of three times could be taken as an absolute upper limit so far as this study is concerned. The figures for duration of stay in Great Britain, type of disease, and age-sex distribution found in the Birmingham notifications agree reasonably well with those reported by Hess and Macdonald.

Brett (1958), on the basis of the proportion found to be tuberculous by mass radiography, has suggested that in parts of London at the present time there is a sevenfold excess of tuberculosis amongst the Irish born. Whilst agreeing that there is an excess in the Irish born, the Birmingham figures based on notifications do not support such a high estimate. Brett's figures show no excess of tuberculosis amongst West Indians, and here the Birmingham figures are in full agreement, and indeed suggest that the West Indian born population has relatively less tuberculosis. The types of disease that are appearing should however sound a warning—the predominance of disseminated disease and pleural effusions suggest very strongly that the immigrants from the West Indies are largely of tuberculin negative stock and are being infected for the first time after entry to this country; there may therefore be a number of later breakdowns from currently silent primary infections.

Studies of tuberculosis in migrants from Asian countries have not previously been reported, but the notification figures from Birmingham suggest that this group includes a large proportion with tuberculosis. Further, the disease is predominantly of a chronic pulmonary type, and some cases with positive sputum have been notified within a very short time of entry to this country. When these facts are taken in conjunction with the known high incidence of tuberculosis in some parts at least of India and Pakistan it seems probable that the great excess of tuberculosis in this group is due more to the migration to this country of individuals already tuberculous than to infection of susceptibles after arrival.

Finally, what measures would be most likely to lead to a reduction of tuberculosis in these immigrant groups? Workers in the tuberculosis service in Great Britain are well aware of the stringent radiographic requirements of many countries receiving emigrants from England, and it is natural to expect that similar examinations could reasonably be required of immigrants to this country. Of the twenty cases notified in Birmingham during 1956–7 from persons born in the West Indies, probably not more than three or four would have been detected by a scheme of chest x-ray on entry operating over the preceding 10 years. Similarly, it is possible that the majority of the Irish immigrants subsequently notified enter Great Britain tuberculin negative and with normal chest *x* rays. In these two groups more is to be expected from B.C.G. vaccination before immigration than from routine radiography before entry. In Ireland extensive B.C.G. vaccination campaigns have been carried out, and the groups fairly completely covered while at school will soon be reaching the age at which migration tends to occur; in the long run this fact, coupled with declining opportunities for infection in the cities of this country, should lead to an adequate answer to the problem of tuberculosis in Irish immigrants to Great Britain.

The total number of Asian born immigrants to Great Britain is fortunately small, but this group includes a very high proportion of tuberculous persons. The most likely cause for this is that they come from communities where tuberculosis is rife,

and if so the appropriate measure is radiological examination before entry to this country. The increase in the number of notifications from this source in 1957 compared with 1956 suggests that this is a problem which is of increasing importance, and likely to be of even greater relative importance as notification rates decline in Great Britain.

Summary

(1) In Birmingham in the years 1956–7 notifications of Irish born persons as tuberculous were approximately twice as numerous as would be expected from the population figures. For Asian born persons the notifications were between four and six times as numerous as would be expected. For West Indian born the notifications were rather less than would be expected.

(2) The excess in the Irish born is probably due to the migration of uninfected young adults into a relatively more infectious environment. The appropriate protective measure is B.C.G. vaccination before migration, and this is now being extensively carried out in Irish schools.

(3) From the type of disease found it is probable that the excess in the Asian born is due to the immigration of persons already having tuberculous lesions. The appropriate protective measure for Great Britain is routine radiography before entry.

We wish to thank the Medical Officer of Health, Dr. Matthew Burn, for the use of the Tuberculosis Register; Mr. Alan Gibbs, Liaison Officer for Coloured People, for assistance with population figures; and our clinical colleagues in the Birmingham Chest Service for the use of patients' records.

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Addendum

The provisional figures for notifications in Birmingham for the first half of 1958 show that the proportion of Asian born persons among those newly notified has risen still further to 9·4 per cent. The proportions of Irish born (13·8 per cent.) and West Indian born (0·8 per cent.) show little change from 1957. The total of notifications in the first half of 1958 is approximately 25 per cent. greater than in the first half of 1957.

Tuberculosis among immigrants from Asia is therefore a problem which continues to increase, both relatively and absolutely.

Brit. J. prev. soc. Med. (1958), **12**, 141–146

A NOTE ON THE INTERPRETATION OF $n \times 2$ TABLES

BY

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Data are frequently acquired or extracted in the form of a contingency table of two rows and several columns, and it is sometimes necessary to consider the distribution of entries into the various cells in terms of consistency with some hypothesis.

Where the ranking order of the columns is of no consequence, the conventional and widely-recommended χ^2 tests may be appropriate, provided the totals in the two rows are not grossly disproportionate in number. If they are grossly disproportionate in number tests based on the ratio of the observed to the expected variance on the assumption of a Poisson distribution are more efficient (Berkson, 1940; Cochran, 1954). These cases in which the ranking order of the columns is inconsequential are comparatively rare, except in relation to genetic segregation.

Almost always the order of the columns is meaningful, and any test which fails to appreciate this is clearly inefficient. The conventional χ^2 test of contingency gives a result which is uninfluenced by arranging the columns in any of $n!$ ways, and this result is related to $n-1$ degrees of freedom, only one or two of which are likely to be related to any biologically meaningful variation. In addition, it is unrelated to any intuitively meaningful estimator.

Nevertheless, cases in which these tests are used on $n \times 2$ Tables in which the order of the columns is obviously meaningful, as in degrees of exposure to therapies, toxins, etc., or in degrees of variation by such attributes bounded by heights, weights, or blood pressures, are very common.

Frequently sufficient information is available to do a "t" test, if necessary after some normalizing transformation, and this will always be preferable to grouping bounded variates as attributes and applying statistical methods based on the sampling of attributes.

The only occasion on which $n \times 2$ Tables can be regarded as an efficient representation of data for analysis is when the ranking order of groups of variates can be specified but there are no estimates of their relative value, or when, as in the case of the distribution of birth order or family size, the variates are limited to integral values.

If data are in the form of an $n \times 2$ Table, and a simple inefficient test for trend is required, it is preferable to lose information by removing partitions, converting the table into a 2×2 Table, than to lose precision by indulging in a multiplicity of degrees of freedom.

This advice need not permit a choice of grouping after examination of the data: the most efficient arrangement, that which maximizes the harmonic mean of the class frequencies or minimizes the sum of their reciprocals (Edwards, 1957b), may form the basis of a simple objective rule. The proportion of information lost cannot exceed

$$1-\frac{2}{\pi} \text{ or } 36{\cdot}3 \text{ per cent.}$$

Many methods have been advanced to overcome the obvious inefficiency of either ignoring ranking order or losing the information provided by some of the partitions. Pearson's biserial correlation coefficient is now rarely used, as it is complicated, the relevant estimator is not always meaningful, and there is no exact method of determining its standard error. Simple regression methods, based on the logistic approximation or on Berkson's Normit Tables (Berkson, 1957), will overcome some of these difficulties. The problem, however, seems

rare in practice, although its logistic approximation may be simulated when a disease is predisposed to by a logarithmic dose response and comparable numbers of control and diseased persons are interrogated in relation to their dosage (Edwards, 1957a).

Yates (1948) presented a simple scoring method for the analysis of trend, and suggested that the score should be based on integral differences. Similar methods have been advanced by Cochran (1954) and Armitage (1955). These have, as their exponents point out, the disadvantage that the scoring is not objective, and that to decide on a scoring system before seeing the data is in practice unrealistic. This can be a very serious objection as when the trend in proportion is constant in direction it is always possible to choose a scoring system which will lead to an infinite variance ratio, and will implicate a single degree of freedom as responsible for the whole of the contribution to the conventional χ^2 test. A consistent trend will be expected from chance alone with the probability of $\frac{2}{n!}$.

A further difficulty is that the investigator has apparently the choice of either basing a test of significance on the variance ratio or on the contribution to linear regression (both of which, incidentally, are negatively correlated with the remaining components of variance which are also included in the conventional χ^2 test if there really is a trend). In addition, it is not clear what meaning should be attached to heterogeneity relevant to an arbitrary scoring system even in a non-biological framework.

Tests of trend in $n \times 2$ Tables are usually considered in terms of regression. It is perhaps simpler to consider the problem in terms of mean scores, which, as Yates (1948) has shown, lead to formally identical tests of significance.

Consider the case in which an event has a probability p_a, $p_b \ldots p_n$ of falling in exclusive and exhaustive categories a, $b, \ldots n$, and let these categories be arbitrarily given numerical scores s_a, $s_b \ldots s_n$.

Then, after N events, the expected mean score will be $\sum ps$, with variance

$$\frac{1}{N}\left(\sum ps^2 - \left(\sum ps\right)^2\right).$$

In the case of an $n \times 2$ Table, as in Table I, the method allows a simple solution to the problem of whether the two rows could reasonably be regarded as samples from the most likely parent population from which the marginal totals may be regarded as samples.

TABLE I

SYMBOLISM DESIGNATING FREQUENCIES IN AN $n \times 2$ TABLE

						Total
	p_1	p_2	p_3		p_n	P
	q_1	q_2	q_3		q_n	Q
Total	n_1	n_2	n_3		n_n	N
Score	s_1	s_2	s_3		s_n	

The expectations of the mean scores of each row will be:

$$\frac{1}{N}\sum ns,$$

and writing

$$d_p = \frac{1}{P}\sum ps - \frac{1}{N}\sum ns$$

$$d_q = \frac{1}{Q}\sum qs - \frac{1}{N}\sum ns$$

$$V_p = \frac{1}{P}\left(\frac{1}{N}\sum ns^2 - \left(\frac{1}{N}\sum ns\right)^2\right)$$

$$V_q = \frac{1}{Q}\left(\frac{1}{N}\sum ns^2 - \left(\frac{1}{N}\sum ns\right)^2\right),$$

$$\frac{d_p^2}{V_p} + \frac{d_q^2}{V_q}$$

will be distributed as a χ^2 with one degree of freedom, and this distribution will be true of any scoring system devised *in ignorance* of the body of the Table.

We may take as an example the numbers of infants of birth rank 2, 3, and 4 in a group of infants suffering from pyloric stenosis (P) and a control group (Q) from the data of McKeown, MacMahon, and Record (1951). While a primiparity effect is common knowledge, it is not unreasonable to ask whether this can be explained as exclusively due to the obvious peculiarities of first births, or whether a trend persists in the 2nd, 3rd, and 4th births. We may do this by considering the mean birth rank in each group (the mean scores) and the significance of its difference (Table II, opposite).

Where the scores are obviously suggested by the data, as in the case above, no problem will arise. In the far commoner case in which the scores refer to such ranked adjectives as "worse", "same", "better", or some other largely arbitrary subdivision, a simple objective rule is required.

By transforming the scores so that they represent the abscissa of a rectangular distribution specified by the marginal totals, this objectivity can be achieved with considerably less computation than is

TABLE II

BIRTH RANK DISTRIBUTIONS OF CASES OF PYLORIC STENOSIS AND CONTROLS

Pyloric Stenosis	Controls		Birth Rank				
p	q	n	s	ps	qs	ns	ns^2
139	271	410	2	278	542	820	1640
57	123	180	3	171	369	540	1620
19	74	93	4	76	296	372	1468
215	468	683		525	1207	1732	4748
$\sum p$	$\sum q$	$\sum n$		$\sum ps$	$\sum qs$	$\sum ns$	$\sum ns^2$
		Means		2·442	2·579	2·535	6·952

$d_p = -0{\cdot}093 \qquad d_q = +0{\cdot}044$

$V_p = \frac{1}{215}(6{\cdot}952 - 2{\cdot}535^2) = 0{\cdot}00244$

$Vq = \frac{1}{468}(6{\cdot}952 - 2{\cdot}535^2) = 0{\cdot}00112$

$\chi^2 = \frac{d_p^2}{V_p} + \frac{d_q^2}{V_q} = 5{\cdot}3$

Difference in mean birth rank = 0·14 in Ranks 2, 3, and 4.

required for the conventional $n \times 2$ χ^2 test. The logical basis is strictly analogous to using the "t" test after applying a normalizing transformation to the total set of observations. As well as being simple to perform, the test involves no reference to tables other than those of χ^2, or its square root, the normal deviate, and provides a very simple estimator of any linear trend. Its use as a test of significance is, of course, only appropriate in those rare circumstances in which a null hypothesis of zero trend is meaningful.

Consider Table I, which shows an $n \times 2$ Table of pairs of numbers $p_1, q_1 \ldots p_n, q_n$ and their marginal totals. On the null hypothesis of zero trend, the most likely proportions falling into the classes in the body of the Table, specified by a symbol in brackets, will be determined by the marginal frequencies, so that:

$$(p_1) = \frac{Pn_1}{N}, \ (q_2) = \frac{Qn_2}{N}, \text{ etc.}$$

using brackets to specify expectations.

Consider now a series of scores linearly related to N and ranging between 0 and 1, so that:

$$s_1 = \frac{\frac{1}{2}n_1}{N}, \ s_2 = \frac{n_1 + \frac{1}{2}n_2}{N}, \ s_k = \frac{n_1 + n_2 + \ldots \frac{1}{2}n_k}{N}.$$

Then, on the null hypothesis, the expectation of

$$\frac{1}{P}\sum ps = \frac{1}{Q}\sum qs = \frac{1}{2},$$

with sampling variance

$$\frac{1}{P}\left(\frac{1}{P}\sum (p)s^2 - \left[\frac{1}{P}\sum (p)s\right]^2\right) = \frac{1}{P}\left(\frac{1}{N}\sum ns^2 - \frac{1}{4}\right)$$

and

$$\frac{1}{Q}\left(\frac{1}{Q}\sum (q)s^2 - \left[\frac{1}{Q}\sum (q)s\right]^2\right) = \frac{1}{Q}\left(\frac{1}{N}\sum ns^2 - \frac{1}{4}\right)$$

respectively.

Call these variances V_p and V_q.

Then, writing

$$d_p = \frac{1}{P}\sum ps - \frac{1}{P}\sum (p)s = \frac{1}{P}\sum ps - \frac{1}{2}$$

$$d_q = \frac{1}{Q}\sum qs - \frac{1}{Q}\sum (q)s = \frac{1}{Q}\sum qs - \frac{1}{2},$$

$$\frac{d_p^2}{V_p} + \frac{d_q^2}{V_q}$$

is distributed as a χ^2 with one degree of freedom.

In the limiting case when $n = 2$, this test of trend reduces to the conventional χ^2 test:

$$\frac{(p_1q_2 - q_1p_2)^2}{(p_1+q_1)(p_2+q_2)(p_1+p_2)} + \frac{(p_1q_2 - q_1p_2)^2}{(p_1+q_1)(p_2+q_2)(q_1+q_2)}$$

$$= \frac{(p_1q_2 - q_1p_2)^2 N}{(p_1+q_1)(p_2+q_2)(p_1+p_2)(q_1+q_2)}.$$

The calculation of $\frac{1}{P}\sum ps$, $\frac{1}{Q}\sum qs$, and V_p and V_q is extremely simple, and may be made easier by presenting the data in the vertical form as in Table III (overleaf).

An example is given in Table IV (overleaf) from date published by Record and McKeown (1949) on the work done by the mother during first pregnancies resulting in malformations of the central nervous system.

In the limiting form when one row total is far less than the other, so that the two with the smaller frequencies may be assumed to follow the Poisson distribution, and the expectations in each group are equal, so that the data present as a single series of numbers, as, for example, deaths per year from some disease for several years in an equal population at risk*, a test for trend is extremely simple.

*Provided the variation in population did not exceed a few per cent the numbers could be "standardized" with advantage; although the numbers might be non-integral the slight bias in the estimates of variance would be trivial compared to the other biases eliminated.

TABLE III

SYMBOLISM USED IN ANALYSIS OF TREND

p	q	n			s*	ps	qs	ns^2
p_1	q_1	n_1	n_1	n_1	s_1	s_1p_1	s_1q_1	$n_1s_1^2$
p_2	q_2	n_2	n_1+n_2	$2n_1+n_2$	s_2	s_2p_2	s_2q_2	$n_2s_2^2$
p_3	q_3	n_3	n_2+n_3	$2n_1+2n_2+n_3$	s_3	s_3p_3	s_3q_3	$n_3s_3^2$
p_4	q_4	n_4	n_3+n_4	$2n_1+2n_2+2n_3+n_4$	s_4	s_4p_4	s_4q_4	$n_4s_4^2$
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
P	Q	N				$\sum ps$	$\sum qs$	$\sum ns^2$

$$d_p = \frac{1}{P}\sum ps - \frac{1}{2} \qquad \chi^2_1 = \frac{d_p^2}{V_p} + \frac{d_q^2}{V_q}$$

$$d_q = \frac{1}{Q}\sum qs - \frac{1}{2} \qquad \Delta_p = 12d_p\left(\frac{P}{N}\right) = \Delta_q = 12d_q\left(\frac{Q}{N}\right)$$

$$V_p = \frac{1}{P}\left[\frac{1}{N}\sum ns^2 - \frac{1}{4}\right] \qquad \{P_k\} = \{P_o\} + s_k\,\Delta p$$

$$V_q = \frac{1}{Q}\left[\frac{1}{N}\sum ns^2 - \frac{1}{4}\right] \qquad \{P_o\} = \frac{P}{N} - 6d_p\frac{P}{N}$$

*Note: $s_1 = \frac{n_1}{2N}$, $s_2 = \frac{2n_1+n_2}{2N}$, etc.

TABLE IV

EXAMPLE OF COMPUTATION OF ANALYSIS OF TREND

Work of Mother	Mal-formations	Con-trols	Sum						
	p	q	n	See Table III		s	ps	qs	ns^2
No work	8	4	12	12	12	0·0102	0·0816	0·0408	0·0013
Own housework with help	27	15	42	54	66	0·0563	1·5201	0·8445	0·1331
Own housework without help	95	104	199	241	307	0·2619	24·8805	27·2376	13·6498
Remunerated employment only	59	17	76	275	582	0·4966	29·2994	8·4422	18·7424
Remunerated employment and own housework with help	37	27	64	140	722	0·6160	22·7920	16·6320	24·2854
Remunerated employment and own housework without help	108	85	193	257	979	0·8353	90·2124	71·0005	134·6611
Total	334	252	586				168·79	124·20	191·47
	P	Q	N				$\sum ps$	$\sum qs$	$\sum ns^2$

$$d_p = \frac{1}{P}\sum ps - \frac{1}{2} = +0{\cdot}00536 \qquad \chi^2 = \frac{d_p^2}{V_p} + \frac{d_q^2}{V_q} = 0{\cdot}293$$

$$d_q = \frac{1}{Q}\sum qs - \frac{1}{2} = -0{\cdot}007215 \qquad \Delta_p = 12d_p\left(\frac{P}{N}\right) = +0{\cdot}037$$

$$V_p = \frac{1}{P}\left[\frac{1}{N}\sum ns^2 - \frac{1}{4}\right] = 0{\cdot}000230 \qquad \Delta_q = 12d_q\left(\frac{Q}{N}\right) = -0{\cdot}037$$

$$V_q = \frac{1}{Q}\left[\frac{1}{N}\sum ns^2 - \frac{1}{4}\right] = 0{\cdot}000304 \qquad \{P_o\} = \frac{P}{N} - 6\,d_p\frac{P}{N} = 0{\cdot}552$$

Consider a series p_1, p_2, $p_3 \ldots p_n$, of total P. Then the sum of the scored frequencies will be

$$\frac{1}{2P}(1p_1 + 3p_2 + 5p_3 + \ldots . (2n-1)\,p_n),$$

with an expectation of $\frac{1}{2}$ and sampling variance of

$$\frac{1}{P}\left(\frac{1}{4n^2}(1^2+3^2+5^2+\ldots(2n-1)^2) - \frac{1}{4}\right),$$

which varies between $\frac{1}{16P}$ when $n=2$ and $\frac{1}{12P}$ when $n=\infty$.

Some values are given in Table V. Algebraically these results are identical with those of Armitage (1955), Formula 8.

TABLE V

VARIANCE OF THE MEAN AND RELATIVE EFFICIENCY OF VARIOUS PARTITIONS OF A RECTANGULAR UNIVERSE

n	Variance of Mean	Efficiency in Equally Divided Rectangular Distribution (per cent.)
2	$\frac{1}{16P}$	75·0
3	$\frac{1}{13{\cdot}500P}$	88·9
4	$\frac{1}{12{\cdot}800P}$	93·8
5	$\frac{1}{12{\cdot}500P}$	96·0
6	$\frac{1}{12{\cdot}343P}$	97·2
7	$\frac{1}{12{\cdot}250P}$	98·0
8	$\frac{1}{12{\cdot}191P}$	98·4
9	$\frac{1}{12{\cdot}150P}$	98·8
10	$\frac{1}{12{\cdot}121P}$	99·0
∞	$\frac{1}{12P}$	100·0

Estimates of linear trend may be obtained directly from the discrepancies d_p and d_q.

If there is a linear trend varying between $\frac{P}{N}-\frac{1}{2}\triangle_p$ and $\frac{P}{N}+\frac{1}{2}\triangle_p$ between the extremes of the distribution, writing $\{p_o\}$ for the proportion at the margin bordered by the class frequencies p_1 and q_1, which we may specify by the score s_o, the proportion associated with the score s_k, say $\{p_k\}$, will be:

$$\{p_k\} = \{p_o\} + s_k\triangle_p, \text{ when } \{p_o\} = \frac{P}{N} - \frac{1}{2}\triangle_p,$$

and a consideration of the first moments of a trapezoid show that:

$$\triangle_p = 12\frac{P}{N}d_p \text{ and } \triangle_q = 12\frac{Q}{N}d_q.$$

Obviously $\triangle_p = \triangle_q$ and this provides a simple check of the arithmetic. Where heterogeneity is meaningful, the computation of expected frequencies from this linear trend will allow a test to be made along the lines of the conventional χ^2 test, and will have $n-2$ degrees of freedom.

Table VI shows a test of trend in frequencies applied to data on the number of men aged 30 to 34 years certified as dying from carcinoma of the lung in England and Wales. The mean increment per year as a percentage of the mean is, when small, approximately equal to the rate of change per year. For computational simplicity a twenty-fold multiple of the scores has been used.

TABLE VI

NUMBER OF DEATHS EACH YEAR DUE TO CARCINOMA OF LUNG AMONG MEN AGE 30–34

Year	p	$s \times 20$	$s \times p \times 20$
1946	50	1	50
1947	67	3	201
1948	69	5	345
1949	57	7	399
1950	59	9	531
1951	47	11	517
1952	56	13	728
1953	66	15	990
1954	65	17	1105
1955	54	19	1026
Total	590		5892
	P		$20\sum ps$
Mean	59·0		0·4993

$$\frac{1}{P}\sum ps = 0{\cdot}4993$$

$$d_p = -0{\cdot}0007$$

$$V_p = \frac{1}{12{\cdot}12P} = 0{\cdot}000140$$

$$\chi^2 = \frac{d^2_p}{V_p} = 0{\cdot}004$$

$$\triangle_p = 12d_p \pm 12\sqrt{V_p}$$
$$= -0{\cdot}009 \pm 0{\cdot}14$$

Mean increment per year as percentage of mean
$= -0{\cdot}1$ per cent. $\pm 1{\cdot}4$ per cent.

It is of interest to observe the very limited advantages of increasing the subdivision beyond 4 or so. The relative efficiency of different numbers of equal divisions in a continuous, and, in principle, infinitely divisible rectangular distribution is given in Table V.

It cannot, however, be concluded from this that the use of scores based on a rectangular transformation allows justifiable simplification of the "t" test for data approximating to the normal distribution or to one of its transformations. The use of a 2×2 Table as a simple test for the difference of means of large normal populations cannot have a higher efficiency than $\frac{2}{\pi}$.

It would appear that the breaking up of two normal distributions into the form of an $n \times 2$ Table cannot have a higher efficiency than

$$\frac{2}{\pi} \times \frac{16}{12} \text{ or } 84{\cdot}9 \text{ per cent.}$$

Summary

The widely-used method of testing for trend by using χ^2 for several degrees of freedom is a less powerful method of detecting trend than the use of a 2×2 test after removing some of the partitions. A rule for deciding which partitions to remove so as to maximize the residual information is advanced.

The loss of the information provided by these subdivisions, though less serious than the loss involved with methods using several degrees of freedom, may be reduced by various well known scoring methods. A system of scoring which is simple to compute, fully objective, and which leads to an intelligible estimate in the case of a rectangular distribution with a linear change in proportion, is advanced.

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Brit. J. prev. soc. Med. (1958), **12**, 147–153

CORONARY AND OTHER HEART DISEASE IN A GROUP OF IRISH MALES AGED 65–85

BY

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In Ireland, as in other countries, the incidence of deaths certified as due to coronary artery disease has increased steadily since the first world war. Thus, in 1955, over thirty men and thirty women were reported as having died from this cause for every man or woman who had died of the same cause in 1926 (Acheson and Thornton, 1958). In such circumstances it is of some interest to study the morbidity due to the disease; the present paper is the first of a series dealing with various aspects of cardiac function and coronary heart disease in a group of elderly Dubliners who had been skilled or unskilled labourers throughout their working lives.

Materials and Methods

The Sample.—The men were pensioners who had been employed by Messrs. Arthur Guinness, Son, and Co. Ltd. in their Dublin Brewery for at least 35 years, and who were aged 65 to 85 years at the time of the study (February–May, 1957). 153 names were selected consisting of all men aged 76 to 85, and one in five aged 65 to 69. Their distribution in quinquennial age groups, together with the percentage attendance in each group is shown in Table I.

TABLE I
SAMPLE

Age Group (yrs)	Number Selected	Number Attended	Per Cent. Attendance
65–69	47	43	91
70–74	47	42	89
75–79	28	21	75
80–85	31	23	74
Total	153	129	84

Of the 24 who failed to attend, seven had died between the time that their names were chosen and the time that the invitations were sent, ten were in-patients in hospital or were otherwise unfit to attend, one had left the country, and six refused to co-operate.

Clinical Examination.—All the men were seen at the Brewery's medical department by one of us (R.M.A.), when a full clinical history was taken, with particular reference to symptoms of cardiovascular disease; notes were also made of habits and past illnesses. A physical examination followed, which included a careful study of the circulatory system and a standard 12-lead electrocardiogram (ECG). Blood pressure was recorded in the recumbent position and the distance between the maximum cardiac impulse and the midline (Wood, 1956) was measured with a linen tape to the nearest quarter inch. With this exception (i.e. locating apex beat), the methods used in conducting the clinical examination conformed as closely as possible with those described by Hunter and Bomford (1956). The men who did not suffer from angina pectoris and in whom no other contraindication to exercise was apparent* were asked to walk backwards and forwards over Master's steps (Master and Oppenheimer, 1926; Master, Friedman, and Dack, 1942), each man wearing terminals on his wrists and ankles, until moderate breathlessness developed. A record was kept of the time taken over the test and of the number of trips made. The subject then lay down on the couch again and was re-connected to the electrocardiograph; between 25 and 30 seconds elapsed between the time that the man had stopped work and the time that the subsequent ECG was commenced. The tracing after exercise was confined to Leads I, II, III, V_5, and V_6, which were recorded in series over a period of 5 to 7 minutes. The exercise test was accepted as being adequate if the pulse rate rose

* Contraindications included abnormalities in ECG other than ectopic beats, osteo-arthritis, varicose ulcers, senile debility, etc

to over 100 beats per minute (Wood, McGregor, Magidson, and Whittaker, 1950). The number of men who performed adequate tests is shown, by age groups, in Table II.

TABLE II

NUMBER OF MEN IN EACH AGE GROUP WHO PERFORMED AN ADEQUATE EXERCISE TOLERANCE TEST

Age Group (yrs)	Number	Per Cent.
65–69	16	37
70–74	19	45
75–79	2	9
80–85	1	4
Total	38	29

Interpretation of Electrocardiograms.—The ECG's were all interpreted by one of us (E.D.A.). Initially a report was made on each tracing without recourse to any information about the patient. Some months later the tracings were read again and the two reports were compared and studied in the light of the clinical findings. In view of the problem of observer error (see below) no attempt was made to record minor abnormalities, such as those attributed to coronary heart disease by Evans and McRae (1952).

RESULTS

POSITION OF THE APEX BEAT.—In the 121 men in whom records were complete and satisfactory in this respect (Fig. 1), the average position of the apex beat was 4·9 inches from the midline. In six of the men (5 per cent.) the apex beat was located in the sixth intercostal space, and in them the mean distance from the midline was 5·3 in.; in one man (0·8 per cent.) it was located in the fourth intercostal space 4·7 in. from the midline; in the remainder (94·2 per cent.) it was located in the fifth intercostal space. (Of the total 129 men, three had a scoliosis sufficient to displace the heart, the apex was impalpable in three, and one had a displaced mediastinum as a consequence of healed tuberculosis.)

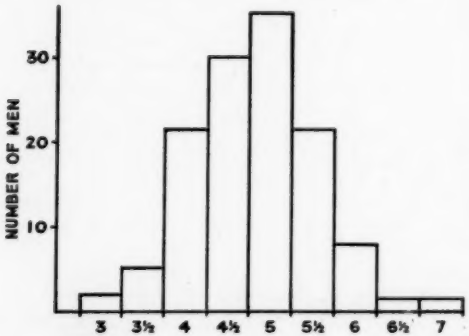

FIG. 1.—Distance of cardiac apex from midline in 121 men aged 65–85 years.

ARTERIAL BLOOD PRESSURE.—The mean systolic blood pressure (mm. Hg.) for the group was 177·6 and the mean diastolic pressure 97·2. In Fig 2 (opposite) the distribution of the readings is shown for the men aged 65–74 years, and for those aged 75 and over.

There was a slight tendency for diastolic pressure to fall with increasing age, but this did not approach statistical significance ($r_{137} = -0{\cdot}019$).

EXERCISE TOLERANCE TEST.—The amount of work and rate of work done by the men who performed adequate exercise tolerance tests is summarized in Table III.

TABLE III

WORK AND RATE OF WORK CARRIED OUT BY THE MEN WHO PERFORMED AN ADEQUATE EXERCISE TOLERANCE TEST

No. of Men	Work (ft. lb.)		Rate of work (ft. lb./sec.)	
	Mean	S.D.	Mean	S.D.
38	4,633·2	528·0	46·7	12·8

FREQUENCY OF CORONARY HEART DISEASE.—The reasons for believing that 53 (41 per cent.) of the men suffered from definite or doubtful coronary heart disease are shown in Table IV (opposite).

Of 24 men with definite cardiac pain, eight had normal and seventeen abnormal ECG's at rest. Three of those whose ECGs were abnormal showed classical signs of myocardial infarcation, ten showed non-specific changes involving the RST segment and T wave, two had complete right bundle branch block, and two were in auricular fibrillation. The six men with doubtful angina pectoris included in Table IV had abnormal tracings; one had an anterior myocardial infarcation, one a complete and one an incomplete right bundle branch block, and four had abnormalities of RST segment and T wave.

Abnormal ECGs with no history of cardiac pain were found in 22 additional patients; one of these had the classical signs of anterior myocardial infarction, and in the remaining 21 the changes were non-specific and it was difficult to be certain to what extent coronary heart disease was responsible for

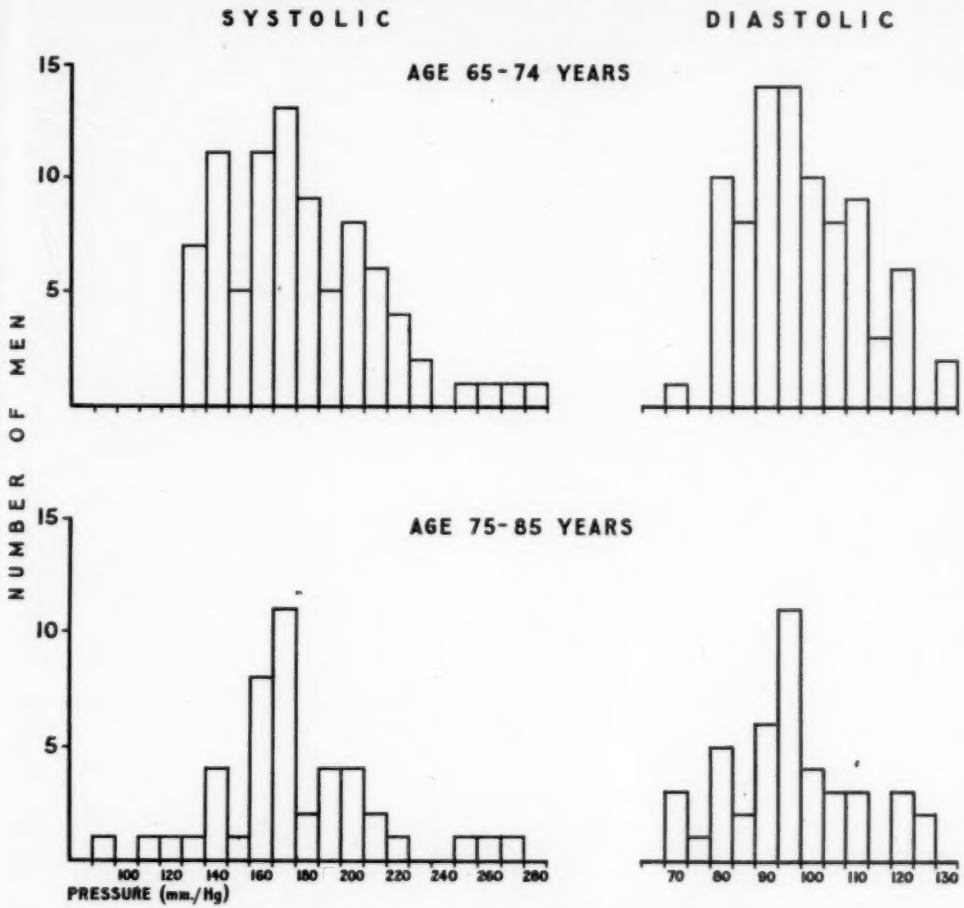

FIG. 2.—Systolic and diastolic blood pressure in 85 men aged 65–74 yrs and 43 men aged 75–85 yrs.

TABLE IV

CRITERIA FOR DIAGNOSIS OF CORONARY HEART DISEASE IN 53 MEN

Signs and/or Symptoms		Number of Cases	
		Definite	Doubtful
(1) Angina Pectoris with or without an Abnormal ECG		25	6
(2) Electrocardiographic Evidence of Myocardial Infarction (without history)		1	0
(3) Electrocardiographic Changes possibly due to Coronary Heart Disease in Men without Angina Pectoris	(*a*) Left bundle branch block (*b*) Right bundle branch block (*c*) Atrial fibrillation without other cause (*d*) RST segment and T wave changes at rest (*e*) RST segment and T wave changes after exercise only		0 1 4 14 2 } 21
Total		26	27

them, particularly as hypertension and clinical evidence of left ventricular enlargement were frequently present also (Table V). In fourteen cases the changes present affected predominantly the RST segment and T wave in left ventricular leads. When the first study was made without knowledge of the subjects' symptoms, the tracings were classified as either "left ventricular hypertrophy" or "ischaemic" patterns. However, the second study, made after an interval and in the light of the symptoms, was most illuminating, for not only did it show that there was a poor relationship between the electrocardiographic diagnosis of these conditions and the clinical facts, but also that the observer could not be sure of repeating his results; thus tracings classified as "ischaemic" on the first occasion were often read as "left ventricular hypertrophy" on the second, and *vice versa*. In view of this unsatisfactory state of affairs, it was decided to place in a single group in Table IV all the men who gave no history of cardiac pain but had RST segment depression of 1·0 mm. or more, or T wave inversion, or both, in left ventricular leads (in the absence of pathological Q waves). It is reasonable to suppose that coronary artery disease played a part in the production of these changes in some cases. In two further men, neither of whom gave a history of cardiac pain, the resting ECG was normal but exercise produced flat or sagging depression of the RST segment of at least 1·00 mm. As these changes were similar to those found after exercise in sufferers from angina pectoris with normal resting ECGs (Wood and others, 1950); the two men were also grouped among the cases of doubtful coronary heart disease.

The distribution into age groups of the 53 men diagnosed as having definite or doubtful coronary heart disease is shown in Table VI. Sixteen men (13 per cent.) were classified as having no evidence of coronary heart disease; these were men who had a normal ECG before and after an adequate exercise test, and who had never experienced angina pectoris.

TABLE VI

FREQUENCY OF CORONARY HEART DISEASE

Age Group (yrs)	Coronary Heart Disease				Indeterminate	
	Definite or Doubtful		Not Detectable			
	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.
65–69	18	42	9	21	16	37
70–74	14	33	7	17	21	50
75–79	9	43	0	0	12	57
80–85	12	52	1	4	10	43
Whole Sample	53	41	17	13	59	46

The diagnosis was considered to be "indeterminate" (44 per cent.) in those:

(1) who were unfit to perform the exercise test for reasons other than angina pectoris,
(2) whose exercise test was considered to be inadequate,

TABLE V

OBSERVATIONS IN 21 MEN IN WHOM THE DIAGNOSIS OF "PROBABLE" CORONARY HEART DISEASE RESTED UPON NON-SPECIFIC ECG CHANGES

Case No.	Age (yrs)	Blood Pressure (mm./Hg)		Distance from Midline of Cardiac Apex (in.)	ECG* Diagnosis on Second Reading
		Systolic	Diastolic		
2	65	140	80	4½	M.I.
9	67	200	110	5½	M.I.
18	69	135	80	4	M.I. (a.e.)
22	70	155	80	3½	L.V.H.
44	68	190	95	4½	M.I. (a.e.)
46	68	200	110	4½	M.I.
50	80	270	120	5½	M.I.
53	81	210	120	5½	L.V.H.
54	81	190	100	5	M.I.
62	82	140	100	5	L.V.H.
64	82	170	90	5½	Fibrillation and L.V.H.
65	82	170	105	5	L.V.H.
83	71	175	100	5½	Fibrillation and M.I.
84	72	205	90	5½	L.V.H.
90	70	270	115	5½	L.V.H.
101	66	180	105	5½	R.B.B.B.
103	65	145	95	4½	Fibrillation
111	73	210	100	4½	M.I.
119	77	150	85	5	Fibrillation
128	79	200	90	5	M.I.
129	85	120	80	5½	L.V.H.

* L.V.H. = Left ventricular hypertrophy. M.I. = Myocardial ischaemia. R.B.B.B. = Complete right bundle branch block. (a.e.) = after exercise.

(3) whose ECG, before or after exercise, showed abnormalities other than those listed above (further details of this group are given in Table VII).

TABLE VII

A FURTHER ANALYSIS OF THE 59 MEN IN WHOM THE DIAGNOSIS WAS CLASSED AS "INDETERMINATE" IN TABLE VI

Observation		No. of Cases
Performed an exercise test, but failed to raise the pulse rate to 100/min.		11
Performed an adequate exercise test, but had the following abnormalities in the ECG:	RST depression of more than 0·5 but less than 1·0 mm.	2
	Ectopic beats	11
	Left axis deviation	1
		} 14
Did not perform an exercise test because of heart disease		6
Did not perform an exercise test for reasons not connected with the heart		25
Imperfect or Inadequate ECG		3
Total		59

Despite the fact that 33 of the men with coronary heart disease admitted to symptoms, only twelve (9·3 per cent.) had consulted their doctor for treatment of the condition before the survey (see Table VIII).

TABLE VIII

MEN WITH SYMPTOMS OF CORONARY HEART DISEASE WHO HAD, OR HAD NOT, CONSULTED THEIR DOCTOR

Symptom	Had Consulted Doctor	Had Not Consulted Doctor	Total
Definite Angina Pectoris	9	16	25
Doubtful Angina Pectoris	1	5	6
Symptoms of Cardiac Failure without Angina Pectoris (atrial fibrillation)	2	0	2
Total	12	21	33

OTHER HEART DISEASE

(*i*) *Degenerative Disease of the Aortic Valve.*—Ten men (8 per cent.) had clinical evidence of stenosis and/or incompetence of the aortic valve; one of these also had angina pectoris together with ECG changes in the RST segment and is included in Table IV. Six of the remaining nine had a systolic blood pressure of over 200 mm. Hg, and five of these a diastolic blood pressure of 100 mm. Hg or more. None of the men with aortic valve lesions had a diastolic pressure of less than 90 mm. Hg.

(*ii*) *Rheumatic Heart Disease.*—Three men (2 per cent.) had rheumatic heart disease.

(*iii*) *Cardiac Failure.*—Four men (3 per cent.) were in congestive heart failure with engorgement of the veins of the neck. One complained of angina pectoris and had atrial fibrillation; two others also had atrial fibrillation and in the absence of valvular disease or thyrotoxicosis it was assumed that this was caused by coronary heart disease, thus they are included in Group 3 in Table IV. The fourth man in congestive heart failure had mitral stenosis. Three other men (2 per cent), all of whom had coronary heart disease, gave a history of paroxysmal nocturnal dyspnoea.

There was little severe chronic bronchitis, and none of the men had cor pulmonale.

(*iv*) *Syphilitic and Congenital Heart Disease.*—As far as we could ascertain, only one man had ever had a positive Wassermann reaction, and he showed no evidence that syphilis had caused cardio-vascular disease. None of the men had congenital heart disease.

DISCUSSION

Our data show that, in a small group of elderly Dubliners, the frequency of definite coronary disease is 20 per cent., the diagnosis being based upon a history of cardiac pain or the classical ECG signs of myocardial infarction in the absence of such a history. In a further 21 per cent., non-specific electrocardiographic signs were interpreted as being due, in part at least, to coronary heart disease. The men are drawn from one social stratum and obviously, therefore, are not representative of the elderly male population of the city; moreover, since Messrs. Guinness have, for about 80 years, subjected their employees to a rigorous physical examination before recruiting them, these men cannot considered a typical sample of the skilled and unskilled labourers in the community. It is, nevertheless, of some interest to compare the frequency of coronary heart disease observed in our sample with frequencies in some other recent reports.

The conduct of the research in each of the previous inquiries differs from that of our inquiry in at least one respect. For example, Sheldon (1948) and Droller and Pemberton (1953) studied people of more or less equivalent age, but included women and saw the patients in their own homes. Sheldon (1948), who did not carry out a physical examination, found the eleven out of 477 (2·3 per cent.) old people in Wolverhampton complained of angina pectoris despite the fact that he asked no direct question about this symptom, and a further three

had had a coronary thrombosis. An additional, 9·4 per cent. of his sample had, at some time, received treatment for high blood pressure, and a further 5 per cent. for heart disease, the nature of which was unknown. Droller and Pemberton (1953) carried out a physical examination in their study of elderly folk in Sheffield, but did not use the electrocardiograph; 20·5 per cent. of their sample of 476 gave a history of angina in response to direct questioning and the distribution was equal in the two sexes. Thus, while no exact comparison can be made between Sheldon's survey and ours, the frequency of angina in the Sheffield study is very similar to that in the Dublin pensioners.

Brown, Davidson, McKeown, and Whitfield (1957) depended upon the co-operation of general practitioners for a survey of cardiovascular disease in 1,062 men aged 60 to 69 years in Birmingham. The practitioners attempted to interview and examine all the men on their lists in the age range which was being studied, and referred those cases which had signs or syptoms suggestive of coronary heart disease to the University Hospital where they were seen by a consultant physician. Confirmation of the diagnosis was established on ECG or other grounds in 8·4 per cent. of the entire sample; only 5·9 per cent. of the sample had angina pectoris however. Even if allowance is made for the fact that these men are in general younger, the frequency either of definite coronary heart disease or angina pectoris is very much lower than that in the Sheffield or the present study. However, only 9·3 per cent. of our sample has sought treatment for their coronary heart disease, *of their own volition*, before the survey.

To our knowledge, apart from our own survey, electrocardiography has been used to screen an entire sample only in men aged under 65. Thus, Thomas, Cotes, and Higgins (1956) diagnosed coronary heart disease in 38 per cent. of a random sample of 47 coal-miners in South Wales; they published the ECGs and some of them would have been classed as "doubtful" rather than "definite" on our rating. Eight (17 per cent.) of their sample complained of angina pectoris (Thomas, Cotes, and Higgins, personal communication), however, so the prevalence of this symptom in their community is similar to the figures for Sheffield and Dublin. If in our series the cases of doubtful and definite coronary heart disease are combined, the frequency rises to 41 per cent., which is again comparable with the Welsh figure.

Electrocardiography has also been used for screening in America, but the men studied there have been younger and the reported frequency of coronary heart disease lower. For instance, Doyle, Heslin, Hilleboe, Formel, and Korns (1957), using an exercise test in addition to clinical assessment and a resting ECG, found a frequency of 7·1 per cent. in a sample of 481 male clerks aged 50–55 years, and Dawber, Moore, and Mann (1957), who did not employ an exercise test, diagnosed coronary heart disease in 9·6 per cent. of a sample of the male inhabitants of Framingham, Massachusetts, aged 55–62 years.

In conclusion, if allowance is made for differences in technique, our estimate of frequency of coronary heart disease in a small group of elderly Dubliners bears close comparison with those for Sheffield (Droller and Pemberton, 1953) and South Wales (Thomas, Cotes, and Higgins 1956) but is much higher than that given in the report from Birmingham by Brown and others (1957). American surveys in which comparable techniques have been used were carried out on younger men.

SUMMARY

A sample of 129 of the pensioners aged 65–85 years on the list of Messrs. Arthur Guinness, Son, and Co. Ltd. (Dublin) were interviewed and examined physically. Values are given for the distance of the cardiac apex from the midline, and for the arterial blood pressure. On the basis of angina pectoris together with an ECG taken before and after exercise, 26 (20 per cent.) were diagnosed as suffering from definite and 27 (21 per cent.) from probable coronary heart disease; the number of subjects suffering from other forms of heart disease is also recorded. Only 9·3 per cent. of the sample had sought treatment for coronary heart disease before the survey. These findings are compared with those of similar studies elsewhere.

We are grateful to the board of directors of Messrs. Arthur Guinness, Son, and Co., Ltd. (Dublin) and to their chief medical officer, Dr. Brian Pringle, both for allowing us to carry out this study and for generously providing us with the necessary accomodation, materials, and technical staff. The quality of the Company's records, which date back over half a century, has added enormously to the value of our data. We would also like to thank Dr. Jack Eustace, Prof. W. J. E. Jessop, and the many other people who have advised and assisted the work.

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ADDENDUM

Since this paper went to press a further prevalence study has been completed in Wales by Thomas, Cochrane, and Higgins (1958), who found that in the opinion of three independent assessors 17 per cent. of a random sample of 85 agricultural workers aged 55–64 had electrocardiographic evidence of coronary heart disease; when patients with symptoms were included the overall prevalence in this sample was 21·3 per cent.

Brit. J. prev. soc. Med. (1958), **12**, 154-155

A NEW METHOD OF STANDARDIZING DEATH RATES

BY

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Two methods of standardizing death rates for age are in common use, the "direct" and the "indirect" Both of these methods require a detailed knowledge of the age structure of the population in which the deaths occur, and the direct method requires the age structure of the deaths in addition. A third method is now suggested which requires only detailed knowledge of age structure of the deaths themselves. This method might conveniently be called Inverse Standardization.

The rate is calculated for each age group in some suitable standardizing population. For deaths, the standardizing population will usually be the whole population of England and Wales,

For any one age group, the number of deaths observed divided by the standard rate for that age group gives an estimate of the size of the group from which the deaths are drawn. The sum of these estimates gives an estimate of the total number in the population. This estimate will be too high if the death rates in the population are higher than the standard death rates, and conversely. The ratio of the estimate of the population to the true number in the population, expressed as a percentage, gives an index of the healthiness of the population, which may conveniently be called the "Inverse Standardized Mortality Ratio".

In a population for which each age-specific death rate is in the same ratio to the corresponding rate in the standard population, the three different methods of standardization give exactly the same result. When the ratios are different, the standard methods give considerably more weight to differences in the higher age groups, while the new method gives weight in proportion to the total number at risk in each age group. This would probably be an advantage in the study of, for instance, occupational mortality, where, as the "Decennial Supplement for 1951" (Registrar General, 1954a) points out, "the swamping effect of the inevitably high mortality" of the older age groups may obscure occupational differences in some circumstances.

The Standard Error of an "Inverse S.M.R" is usually higher than that of the corresponding ordinary S.M.R., especially if one or more of the age-specific death rates in the standardizing population is much lower than the others. For this reason it would not be a suitable index for mortality in a population containing both children and adults.

In general, the usefulness of the Inverse S.M.R lies in its power to use information that would be inadequate for other methods. For instance, in analysing the death rates of a county borough, the age structure of social class groups or municipal ward populations is rarely known, but the total populations are available. When it is possible to use the ordinary S.M.R, however, this is to be preferred, as its standard error is smaller.

If R_1, R_2 . . . etc. are the age-specific rates in the standardizing population, x_1, x_2, . . . etc. are the number of deaths observed in the population being studied, and P is the total number at risk,

The inverse S.M.R. is:

$$\frac{100}{P} \times \left(\frac{x_1}{R_1} + \frac{x_2}{R_2} \cdots \right)$$

and its standard error is:

$$\frac{100}{P} \times \sqrt{\left(\frac{X_1}{R^2_1} + \frac{x_2}{R^2_2} \cdots \right)}.$$

JUSTIFICATION FOR THESE FORMULAE

Let $p_1, p_2, \ldots$ be the number of persons in each age group in the population being studied.

The expected value of x_i, on the assumption that this population is not different from the standardizing population, is $p_i R_i$ (where i takes the values 1, 2, . . . etc.).

The expected value of the inverse S.M.R is therefore:

$$\frac{100}{P} \times \left(\frac{p_1 R_1}{R} + \frac{p_2 R_2}{R_2} + \dots \right)$$
$$= \frac{100}{P} \left(p_1 + p_2 + p_3 + \dots \right) = 100,$$

and is therefore independent of the age structure of the population.

To a first approximation, the number of deaths x_i may be taken to be normally distributed with variance x_i, so that $\frac{x_i}{R_i}$ has variance $\frac{x_i}{R_i^2}$.

The approximation is a little crude, but it is usual in this type of work. For example, the "Decennial Supplement for 1951" (Registrar General, 1954b) gives a variance for the inverse S.M.R. of:

$$\left(\frac{100}{P}\right)^2 \left(\frac{x_1}{R^2_1} + \frac{x_2}{R^2_2} + \dots \right),$$

and the standard error is:

$$\frac{100}{P} \sqrt{\left(\frac{x_1}{R^2_1} + \frac{x_2}{R^2_2} + \dots \right)}.$$

Calculation

Comparison of the Inverse and Ordinary S.M.R

The figures, taken from the "Statistical Review England and Wales for 1954" (Registrar General, 1955), represent the deaths from bronchitis for men aged 25+ in rural areas. The standardizing population is the whole population of England and Wales for the same year.

(a) Calculation of Indirect S.M.R

Age (yrs)	Population at Risk (thousands)	Standard Rate (per thousand)	Expected Deaths
25–44	1,198	·03818	45·74
45–64	990	·97678	967·01
65–74	293	4·34710	1,273·70
75+	149	8·58295	1,278·86
Total	2,630	Total Expected	3,565·31

Observed Deaths (Ages 25+) = 2,384
S.M.R. (100 × Observed ÷ Expected) = 67
Standard Error = 100 √(2384) ÷ 3,565·31
= 4,882·62 ÷ 3,565·31 = 1·4

(b) Calculation of Inverse S.M.R

(The same notation is used as before: x = No. of deaths, R = age-specific death rate per 1,000 in standardizing population.)

Age (yrs)	x	$1/R$	x/R	x/R^2
25–44	40	26·1917	1,047·67	27,440·21
45–64	601	1·0238	615·30	629·95
65–74	817	·2300	187·91	43·22
75+	926	·1165	107·88	12·57
Total	2,384	Estimated population	1,958·76	28,125·95

Actual Population = 2,630 thousand.
Inverse S.M.R = 100 × 1,958·76 ÷ 2,630 = 74
Standard Error = 100 × √(28,125·95) ÷ 2,630
= 16,770·51 ÷ 2,630 = 6·4

This illustrates the fact that the standard error of the Inverse S.M.R. is usually greater.

Summary

A new method of standardization is suggested which may be used when the age structure of the population in which the observed deaths occur is not known. The information required consists of the total population, the age structure of the deaths themselves, and the age-specific death rates in some suitable standardizing population. This is exactly the information most readily available in some practical problems.

The method is not recommended when the standard methods are possible.

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Brit. J. prev. soc. Med. (1958), **12**, 156–158

HOSPITAL SIZE AND STAFF SICKNESS RATES

BY

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It has been shown for various industries that the morale of the staff is closely related to the size of the organization. Thus, for an industrial combine of ninety units, Acton Society Trust (1954) found a clear relationship between size (ranging from 8 to 11,000 employees) and morale measured in terms of sick leave, number of accidents, and length of time taken to recover from an accident. In a similar type of investigation in coalfields, lost time was found to increase with the size of the pit. Moreover, under similar geological conditions, output per man-shift tended to be no higher—and was often appreciably lower—in large pits than in small. Any general improvement in output tended to be more marked in the smaller pits.

A detailed study of the relationship between size and morale in five selected firms confirmed the impression obtained in the general survey (Acton Society Trust, 1957). The connecting link appeared to be "management". As firms grew in size, so the management became more remote and impersonal and, in turn, the worker developed a lack of responsibility towards his job. It was felt that morale could be raised in large organizations by the development of small working units under competent managers.

More recently, Professor Revans, in an address to the Conference on Hospital Authorities and Staff Public Administration (Revans, 1957), quoted figures to show that the accident rate in American hospitals was related to the size of the hospital. The rate, based on 4,680 hospitals in the United States employing over 800,000 (the bulk of whom were nurses), for the year 1953, showed an increase from 2·6 per million employee-hours exposure in hospitals employing less than ten persons to 13·0 in hospitals employing over one thousand persons.

Material

An opportunity for examining the association between the size of the hospital and the sickness absence of nurses in the hospitals of the United Oxford Hospitals and Oxford Regional Hospital Board was presented in the special survey of nurses' absence. This survey covered all sickness and non-sickness absence experienced by all nursing staff during the year ending March 31, 1957. A census of the staff at risk, on lines similar to the national census, was taken half-way through the survey. As a result, a considerable volume of material is available on many different aspects, the details of which will be published later. For present purposes the material is confined to sickness absences among student nurses, because they were the most homogeneous and sensitive group. In particular, the students were roughly of the same age and length of service so that any observed differences would be unlikely to arise in this respect. Further, the hospitals at which the students were employed had to comply with a certain basic minimum standard prescribed by the General Nursing Council, which entails a certain degree of uniformity between the hospitals considered. A possible disadvantage of limiting the comparison to students is that only 51 of the 103 hospitals surveyed had a nurse-training scheme and are thus included in the analysis. But, this group embraces a considerable range both in size of hospital unit and volume of work performed, so that the disadvantage is relatively unimportant.

Results

The number of days absent through sickness are given according to the number of students employed at the hospital (Table I), the average number of available beds (Table II), and the turnover of patients per bed per annum (Table III). In each Table the expected number of days has been calculated on the null hypothesis, namely that there is no difference between the sickness absence at the various hospitals. The average length of absence is the observed number of days absent in the particular group of students divided by the total number of students in that group. The proportion of time lost is the total duration of all spells of sickness that occurred partly or wholly within that period divided

TABLE I

SICKNESS ABSENCE AMONG STUDENT NURSES FOR 12 MONTHS ENDING 31 MARCH, 1957, ANALYSED ACCORDING TO NUMBER OF STUDENT STAFF EMPLOYED AT THE HOSPITAL, NUMBER OF OBSERVED DAYS ABSENT, AND NUMBER OF DAYS ABSENT EXPECTED ON THE NULL HYPOTHESIS, AVERAGE LENGTH OF ABSENCE, AND PROPORTION OF TIME LOST

Number of Students Employed at Hospital	Number of Hospitals	Total Students Employed	Number of Days Absent		Ratio of Observed to Expected (per cent.)	Average Length of Absence per Student (days)	Proportion of Time Lost (per cent.)
			Observed	Expected			
1–	11	23	167	199·55	84	7·26	2·15
5–	11	67	399	581·31	67	5·96	1·77
10–	6	71	907	616·02	147	12·77	3·79
15–	4	64	770	555·28	139	12·03	3·57
20–	5	106	906	919·69	99	8·55	2·54
25–	1	25	383	216·91	177	15·32	4·55
30–	0	—	—	—	—	—	—
35–	1	39	229	328·38	68	5·87	1·74
40–	1	42	396	364·40	109	9·43	2·80
45–	1	47	317	407·79	78	6·74	2·00
50–	1	50	389	433·82	90	7·78	2·31
55–	0	—	—	—	—	—	—
60–	1	63	361	546·61	66	5·73	1·70
65–	1	65	935	563·96	166	14·38	4·27
70–	1	74	1,060	642·05	165	14·32	4·25
75–	0	—	—	—	—	—	—
80–	0	—	—	—	—	—	—
85–	2	174	1,055	1,509·68	70	6·06	1·80
90–	1	91	531	789·54	67	5·84	1·73
95–	0	—	—	—	—	—	—
100+	3	686	5,832	5,951·94	98	8·50	2·52
Total	51	1,687	14,637	14,637	100	8·68	2·57

TABLE II

SICKNESS ABSENCE AMONG STUDENT NURSES FOR 12 MONTHS ENDING 31 MARCH, 1957, ANALYSED ACCORDING TO NUMBER OF AVAILABLE BEDS AT THE HOSPITAL, NUMBER OF OBSERVED DAYS ABSENT AND NUMBER OF DAYS ABSENT EXPECTED ON THE NULL HYPOTHESIS, AVERAGE LENGTH OF ABSENCE, AND PROPORTION OF TIME LOST

Number of Available Beds	Number of Hospitals	Total Students Employed	Number of Days Absent		Ratio of Observed to Expected (per cent.)	Average Length of Absence per Student (days)	Proportion of Time Lost (per cent.)
			Observed	Expected			
1–	3	8	0	69·41	0	0	0
25–	8	30	91	260·29	35	3·03	0·90
50–	4	44	430	381·76	113	9·77	2·90
75–	8	111	1,404	963·07	146	12·65	3·75
100–	3	56	421	485·87	87	7·52	2·23
125–	3	49	325	425·14	76	6·63	1·97
150–	3	84	1,183	728·81	162	14·08	4·18
175–	1	21	145	182·20	80	6·90	2·05
200–	3	35	287	303·67	95	8·20	2·43
225–	1	91	531	789·54	67	5·84	1·73
250–	3	89	711	772·19	92	7·99	2·37
275–	0	—	—	—	—	—	—
300–	3	220	1,280	1,980·79	67	5·81	1·73
400–	2	94	695	815·57	85	7·39	2·19
500–	2	508	4,868	4,407·56	110	9·58	2·84
750+	4	247	2,266	2,143·05	106	9·17	3·67
Total	51	1,687	14,637	14,637	100	8·68	2·57

by the total duration of exposure to risk in the period (General Register Office, 1954). In this instance the period of exposure to risk was assumed to be 337 days (*i.e.* 365 days less 28 days statutory leave). The average sickness period is related to the proportion of working time lost by the reciprocal of the number of possible working days.

Tables I to III show that there was no apparent association between sickness absence rate and the size of the hospital measured in terms of students employed, or average number of available beds, or turnover per bed. This is confirmed by the product-moment correlation analysis of Table IV (overleaf).

DISCUSSION

The lack of association between hospital size and rate of staff sickness absence in this analysis of student nurses' records compared with the reasonably close association found in a variety of industrial occupations may be due to a number of factors.

First, since the analysis is based on one year's observations only, the results may be fortuitous. The Acton Society Trust (1957), for instance, found that lost time records varied considerably from year to year.

Secondly, there is a considerable difference between the size of the hospitals in this survey and

TABLE III

SICKNESS ABSENCE AMONG STUDENT NURSES FOR 12 MONTHS ENDING 31 MARCH, 1957, ANALYSED ACCORDING TO TURNOVER OF PATIENTS PER BED AT THE HOSPITAL, NUMBER OF OBSERVED DAYS ABSENT, AND NUMBER OF DAYS ABSENT EXPECTED ON THE NULL HYPOTHESIS, AVERAGE LENGTH OF ABSENCE, AND PROPORTION OF TIME LOST

Turnover per Bed per Annum	Number of Hospitals	Total Students	Number of Days Absent		Ratio of Observed to Expected (per cent.)	Average Length of Absence per Student (days)	Proportion of Time Lost (per cent.)
			Observed	Expected			
1—	6	274	2,636	2,377·31	111	9·62	2·85
2—	7	51	468	442·49	106	9·18	2·72
4—	6	46	382	399·11	96	8·30	2·46
6—	2	25	145	216·91	67	5·80	1·72
8—	4	134	893	1,162·62	77	6·66	1·98
10—	1	2	32	17·35	184	16·00	4·75
12—	1	89	593	772·19	77	6·66	1·98
14—	3	73	540	633·37	85	7·40	2·20
16—	1	12	282	104·12	271	23·50	6·97
18—	2	12	32	104·12	31	2·67	0·80
20—	5	124	1,464	1,075·86	136	11·81	3·50
22—	2	26	219	225·58	97	8·42	2·50
24—	1	47	317	407·79	78	6·74	2·00
26—	1	1	0	8·68	0	0	0
28—	4	155	1,411	1,344·83	105	9·10	2·70
30—	2	418	3,980	3,626·69	110	9·52	2·83
32—	2	183	964	1,587·76	61	5·27	1·56
34–36	1	15	279	130·14	214	18·60	5·52
Total	51	1,687	14,637	14,637	100	8·68	2·57

TABLE IV

CORRELATION (*r*) BETWEEN PROPORTION OF WORKING TIME LOST AND CERTAIN INDICES OF HOSPITAL SIZE

Variables Correlated		Co-efficient of Correlation (*r*)	t	*P*
Working Time Lost (per cent.) and	(1) Number of Students Employed	+0·16	1·13	0·3>P>0·2
	(2) Average Available Beds per Annum	+0·10	0·70	0·5>P>0·4
	(3) Turnover per Bed per Annum	−0·12	0·85	0·4>P>0·3

that of the industrial firms or American hospitals on which other observations have been based. The largest hospital included in this survey had less than 1,300 beds and the largest group of students employed at any one hospital was 379. In contrast, the Acton Society Trust covered firms with up to 10,000 employees in the general survey and firms with from 58 to 3,500 employees in the subsequent detailed study. The accident rates in American hospitals were based upon hospitals in which the number of employees ranged from less than ten to more than a thousand. In both instances, however, the greatest relative increase in the proportion of time lost in industry and in the accident rate in hospitals occurred between the small and the middle-sized units.

Thirdly, the present analysis relates only to student nurses whose conditions of service and age are relatively homogeneous between hospitals, whereas the comparable analysis in industry is concerned with all workers, irrespective of the type of work performed, age, or length of service. A closer parallel to the industrial survey would be provided by the total sickness rates for all hospital staff. This information is not available at present.

The tentative conclusion to be drawn from this survey is that the size of a hospital or the volume of work has no bearing on the sickness absence of student nurses. Other similar surveys for student nurses as well as for other hospital staff are required before any firm conclusions can be reached regarding the effect of the size of the hospital on staff sickness rates.

SUMMARY

(1) Sickness absence ratios for student nurses during the year ended March 31, 1957, at 51 hospitals were correlated with the size of the hospital as measured in terms of the number of students employed; the average number of available beds; and the turnover per bed.

(2) There was no evidence to show that the rate of sickness absence was related to the size of the hospital.

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